III. *Conclusion of the Experiments and Observations concerning the Attractive Powers of the Mineral Acids.* By Richard Kirwan, *Esq. F. R. S.*

Read Dec. 12, 1782.

HAVING found, as exactly as I was able, the quantity of each of the mineral acids taken up at the point of saturation by alkalies and earths, and also that taken up by phlogiston, when these acids are by it converted into an aërial form, I next endeavoured to find how much of these acids was taken up at the point of saturation by each of the metallic substances, and for this purpose procured the most saturated solution possible of each metallic substance soluble in any of these acids. These solutions did not, indeed, immediately answer my purpose, as they constantly retained an excess of acid; yet as they were the foundation of my subsequent observations, and as the experiments themselves are in many respects useful to be known, I shall here briefly relate their result, and confine myself to those circumstances singly that relate to my future investigations, or that have not heretofore been satisfactorily explained. The acids I used were dephlogisticated so far as to be colourless; the metals were for the most part very fine filings, or reduced in a mortar to a fine powder. They were added little by little to their respective menstruums, much more being thus dissolved than if the whole was thrown in at once; and the solution was performed in glass phials with bent tubes.

Solution

Solution of iron in the vitriolic acid.

100 grs. of bar-iron, in the temperature of 56°, require for their folution, 190 grs. of real acid, whofe proportion to that of the water with which it fhould be diluted, is as 1 to 8, 10, or 12. It would act on iron, though its proportion were greater or leffer, but not fo vigouroufly. If towards the end a heat of 200° were applied, 123 grs. of real acid would be fufficient.

The air produced by this folution is intirely inflammable, and generally amounts to 155 cubic inches.

Iron is alfo foluble with the affiftance of a ftrong heat, and in fmaller quantity in concentrated vitriolic acid; and in this cafe fcarce any inflammable air is produced, but a large quantity of vitriolic air as Dr. PRIESTLEY has obferved, and a fmall quantity of fulphur fublimes at the latter end. This fact is a clear refutation of Mr. LAVOISIER's hypothefis; for is it not evident, that the fame fubftance which, when a dilute acid is ufed, goes off in the form of inflammable air, does when a concentrated acid is ufed, to unite this acid, and thus form both vitriolic air and fulphur? In the firft cafe it cannot unite to the acid, by reafon of the large quantity of water combined with the acid; and as the liquor, being moftly aqueous, contains a large quantity of fpecific fire, it receives that fire when the acid unites to the metallic earth, and flies off in the form of air. But in the fecond cafe, the concentrated acid, containing much lefs fpecific fire, cannot expel the phlogifton in the form of inflammable air (as this air abforbs a vaft quantity of fire) but unites to it, when by heat it is further ftripped of its water, and thus forms both

vitriolic air and fulphur. 100 grs. of iron, diffolved without heat, afford upwards of 400 of vitriol.

100 grs. of the vitriol cryftallized contain 25 of iron, 20 of real acid, and 55 of water. When calcined nearly to rednefs thefe cryftals lofe about 40 of water.

The calces of iron are more or lefs foluble in this acid according to their degree of dephlogiftication. Thofe that are phlogifticated (as that recently precipitated from a folution of vitriol by fixed alkalies) are alfo moft foluble, and upon eva-poration afford cryftals, though paler than thofe formed of ge-nuine iron. Thofe that are leaft phlogifticated are alfo leaft foluble, that is, require more real acid for their folution, and afford no cryftals, but only a magma or mother liquor. Hence alfo, folutions of iron newly made diminifh, and confequently phlogifticate the fuper-incumbent air, and confequently gra-dually emit phlogifton : and hence the calx, being more de-phlogifticated, gradually falls unlefs more acid be added to keep it in folution.

Iron in the nitrous acid.

100 grs. of iron, to be perfectly diffolved, and not barely calcined, require 142 grs. of real nitrous acid, fo diluted as that its proportion to water fhould be as 1 to 13 or 14; and when this laft proportion is ufed, the heat of a candle may be applied for a few feconds, and the accefs of common air pre-vented. In this cafe not above 18 cubic inches of nitrous air are produced, all the reft is abforbed by the folution, and no red vapours appear. But if the proportion of acid and water be as 1 to 8 or 10, and heat be applied, a much greater quantity of iron will be dephlogifticated, though very little of it be held in folution; and by this means I have obtained from 100 grs. of iron, 83,87 cubic inches

of nitrous air; and by diftilling the folution a ftill greater quantity may be obtained, which was abforbed by the folution. No inflammable air is obtained from folutions of iron or any other metallic fubftance in the nitrous acid, becaufe this acid has lefs affinity to water, and more to phlogifton, than the vitriolic acid, and alfo contains much lefs fire than either the vitriolic or marine acids, as will be feen in the fequel, and therefore unites to phlogifton inftead of barely expelling it. And hence it is, that the vitriolic acid, though united with 30 times its weight of water, will ftill vifibly act on iron, and feparate inflammable air in the temperature of $55°$; whereas nitrous acid, diluted with 15 times its weight of water, will have no vifible effect on iron in that temperature.

The calces of iron, if not too much dephlogifticated, are alfo foluble, though difficultly, in the nitrous acid.

Iron in the marine acid.

100 grs. of iron require 215 of real marine acid for their folution. The proportion of acid to that of water in the fpirit of falt I ufed was as 1 to 4. When it is as 1 to 4, it effervefces too violently. Heat is rather prejudicial, as it volatilifes the acid. No marine air flies off, and the quantity of inflammable air is juft the fame as if dilute vitriolic acid were ufed.

The calces of iron are alfo foluble in marine acid. They may be diftinguifhed from genuine iron in this, that their colour, when precipitated by fixed alkalies, is *reddifh*, whereas the precipitate of genuine iron is *greenifh.*

Copper in the vitriolic acid.

100 grs. of copper require nearly 183 grs. real vitriolic acid for their folution. The proportion of acid to that of water

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being as 1 to $\frac{1}{2}$, or at leaft as 1 to $\frac{7}{10}$, and a ftrong heat muft alfo be applied. I could never diffolve the whole of any quantity of copper; but to diffolve a given quantity of it, a ftill greater muft be ufed in the proportion of nearly 28 to 100, though this refiduum alfo is foluble by adding more acid. When copper has been dephlogifticated in this manner, a folution of it is obtained by adding warm water to the dephlogifticated mafs.

The dephlogiftication of 128 grs. of copper treated in this manner affords 11 cubic inches of inflammable air, and nearly 65 of vitriolic air. When I obtained inflammable the acid was a little more aqueous. The reafon why copper cannot be dephlogifticated by dilute vitriolic acid, nor even by the concentrated, without the affiftance of a ftrong heat, as iron is, appears deriveable from its much ftronger attraction to phlogifton, and the much greater quantity of it which copper contains, as will hereafter be feen. Hence

100 grs. of vitriol of copper contain 27 of copper, 30 of acid, and 43 of water, of which it lofes about 28 by evaporation or flight calcination.

The folution of 100 grs. of copper affords 373 of blue vitriol.

Copper in nitrous acid.

100 grs. of copper require 130 of real nitrous acid to diffolve them. If the acid be fo far diluted as that its proportion to that of water be as 1 to 14, the affiftance of heat will be neceffary, otherwife not. This folution affords $67\frac{1}{2}$ cubic inches of nitrous air.

The calces of copper are alfo foluble in this acid.

Copper

Copper in marine acid.

100 grs. of copper require 1190 grs. of real marine acid to diffolve them, and also the affiftance of a moderate heat, the proportion of acid to that of water being as 1 to $4\frac{1}{3}$, that is, its fpecific gravity being 1,186, if a greater heat be ufed, more of the acid will be requifite, as much will be diffipated. If the acid be more concentrated, it will act more vigoroufly.

In my laft paper I mentioned, that $8\frac{1}{2}$ grs. of copper afforded 86 of marine air: however, I muft now add a circumftance which I then did not attend to, which is, that the mercury over which that air was received was acted upon, fo that part of the air was due to this action, which invalidates the conclufion I there drew concerning the quantity of phlogifton in marine air, which hence appears to be greater than I there eftimated it.

The calces of copper are alfo foluble in this acid, though not fo eafily as in the nitrous acid.

Tin in the vitriolic acid.

100 grs. of tin require for their perfect folution 872 grs. of real vitriolic acid, whofe proportion to water fhould not be lefs than as 1 to $\frac{9}{10}$, and alfo the affiftance of a ftrong heat; when the action of the acid has ceafed, fome hot water fhould be added to the turbid folution, and the whole again heated. This folution affords 70 cubic inches of inflammable air. Tin is alfo foluble in a more dilute acid, but not in fo great quantity.

The calces of tin (except that precipitated from marine acid by fixed alkalies) are infoluble in this acid.

Tin

Tin in the nitrous acid.

100 grs. of tin require, for their perfect solution, 1200 grs. of real nitrous acid, whose proportion to water should be at least as 1 to 25, and the heat not exceeding 60° : the quantity of air afforded by such solution is only ten cubic inches, and it is not nitrous. The solution is not permanent; for in a few days it deposits a whitish calx, and if the weather be warm bursts the phial. The calces of tin are insoluble in this acid.

Tin in the marine acid.

100 grs. of tin require for their solution 413 of real marine acid, whose proportion to water is as 1 to $4\frac{1}{2}$, and also the assistance of a moderate heat. This solution affords about 90 cubic inches of inflammable air and 10 of marine air. The calces of tin are nearly insoluble in this acid.

Lead in the vitriolic acid.

100 grs. of lead require for their solution 600 grs. of real acid, whose proportion to water is not less than that of 1 to $\frac{7}{10}$, and better if the quantity of water be still less; and hence, as with regard to copper, a greater quantity of lead should be employed than is expected to be dissolved. A strong heat is also requisite, and hot water should be added to the calcined mass, though sparingly, as it occasions some precipitation.

This metal is also soluble, but in a very small degree, in dilute vitriolic acid; for it effervesces with spirit of vitriol whose specific gravity is only 1,275.

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The calces of lead are ſomething more ſoluble in this acid. 100 grs. of vitriol of lead, formed by precipitation, contains 73 of lead, 17 of real acid, and 10 of water. Vitriol of lead, formed by direct ſolution, contains a large proportion of acid.

Lead in the nitrous acid.

100 grs. of lead require for their ſolution about 78 grs. of real acid, whoſe proportion to that of water may be as 1 to 11 or 12, and the aſſiſtance of heat towards the end. This ſolution affords but eight cubic inches of nitrous air. The calces of lead are alſo ſoluble in this acid; but if much dephlogiſticated they become leſs ſoluble.

100 grs. of minium require 81 grs. of real acid.

100 grs. of nitrous ſalt of lead contain about 60 of lead.

Lead in the marine acid.

100 grs. of lead require 600 grs. of real acid to diſſolve them, when the ſpecific gravity of the ſpirit of ſalt is 1,141, and alſo the aſſiſtance of heat, by which much of the acid is diſſipated. A ſtronger acid would diſſolve more.

The calces of lead are more ſoluble in this acid than genuine lead. 100 grs. minium require 327 grs. of real acid; but white lead is much leſs ſoluble.

100 grs. of horn lead, formed by precipitation, contain 72 of lead, 18 of marine acid, and 10 of water.

Silver in the vitriolic acid.

100 grs. of pure ſilver require to diſſolve them 530 grs. of real vitriolic acid, whoſe proportion to water is not leſs than that of 1 to $\frac{3}{10}$, and when ſuch a concentrated acid is uſed, it acts ſlightly even in the temperature of 60°; but for a copious

ſolution

folution a moderate heat is requifite. This folution affords 30 cubic inches of vitriolic air. Standard filver affords more air and requires more acid for its folution. The calces of filver (that is, filver precipitated from its folution in nitrous acid by fixed alkalies, and well-wafhed, but which ftill retains fome nitrous acid), are foluble even in dilute vitriolic acid, without the affiftance of heat. 100 grs. of vitriol of filver, formed by precipitation, contain 74 grs. of filver, about 17 of real acid, and 9 of water.

Silver in the nitrous acid.

100 grs. of the pureft filver require for their folution 36 of mere nitrous acid, diluted with water in the proportion of one part real acid to 6 of water, applying heat only when the folution is almoft faturate. If fpirit of nitre be much more or much lefs dilute, it will not act without the affiftance of heat. The laft portions of filver, thus taken up, afford no air. *Standard* filver requires about 38 grs. of real acid to diffolve the fame proportion of it. And the folution of it affords 20 cubic inches of nitrous air, whereas 100 grs. of filver, revived from *luna cornua*, afford about 14.

Silver in the marine acid.

I have not been able to diffolve filver, in its metallic ftate, in fpirit of falt, yet I believe it may be effected, if fufficient time be allowed, as Mr. BAYEN, in his Treatife on Tin, p. 201. fays, he diffolved 3½ grs. of filver by digefting it for fome days in two ounces of ftrong fpirit of falt. Leaf filver is alfo faid to be corroded by ftrong fpirit of falt, 1 NEWM. 70. The dephlogifticated marine acid alfo diffolves it, according to the obfervations of Meff. SCHEELE and BERGMAN: and fo does the phlogifti-

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cated in a vaporous ftate.   100 grs. of horn filver contain 75 of filver, nearly 18 of acid, and 7 of water.

Gold in aqua regia.

I made feveral experiments with aqua regia, in which the nitrous and marine acids were mixed in different proportions, and found *that* to fucceed beft, in which the quantity of real marine acid was to that of the nitrous as 3 to 1, and both as concentrated as poffible.; though if both be very concentrated, it is hard to mix them fo as to prevent a great quantity from efcaping, as they effervefce very violently fome time after mixture.   100 grs. of gold require 246 grs. real acid for their folution, the two acids being in the above mentioned proportion.

The fpecific gravity of the nitrous acid I ufed was 1,465, and that of the marine 1,178.   The folution is better promoted by allowing it fufficient time than by applying heat.   The heat I ufed did not exceed 90 or 100°.   Very little air is produced, and the folution is very flow.   Aqua regia made with common falt or fal ammoniac and fpirit of nitre is much lefs aqueous, than that refulting from an immediate combination of both acids; and hence is the fitteft for the production of cryftals of gold.

Gold is alfo foluble in the dephlogifticated marine acid, but in very fmall quantity, unlefs this acid be in a vaporous ftate, for in a liquid ftate it is too aqueous.   In vitriolic and nitrous acids it is alfo infoluble ; but the calces of gold are eafily foluble in the marine acid, very flightly in the nitrous, and fcarce at all in the vitriolic.   Gold in its metallic ftate may be diffufed through, but not diffolved, by the concentrated nitrous acid.

Mercury in vitriolic acid.

100 grs. of quickfilver require for their folution 230 grs. of real vitriolic acid, whofe proportion to that of water is at leaft as 1 to $\frac{8}{10}$, and alfo a ftrong heat. The air produced is vitriolic. Precipitate, *per fe*, is ftill lefs foluble.

100 grs. of vitriol of mercury, produced by precipitation, contain 77 of mercury, 19 of acid, and 4 of water.

Mercury in nitrous acid.

100 grs. of mercury are diffolved by 28 grs. of real nitrous acid, whofe proportion to that of water is as 1 to 1 and $\frac{52}{100}$, and without the affiftance of heat. Mercury is alfo foluble, but in fmaller quantity, in a much more dilute acid, with the affiftance of heat. The product of air is about 12 cubic inches or lefs, if heat be not applied. Mr. LAVOISIER found the pro-duct of air much greater, which evidently was caufed by his ufing red or yellow fpirit of nitre, which already contains much phlogifton. When I diffolved a hundred grs. of mercury in three times more acid than was neceffary for its folution, and without heat, I obtained but 7 cubic inches of nitrous air, and the folution was green; but, on applying heat when the folu-tion was over, I obtained 2 more cubic inches, and then the folution was of the colour of oil of olives.

Precipitate, *per fe*, is much more difficultly diffolved by nitrous acid than genuine mercury, which I attribute to the attraction of the aërial acid contained in the precipitate.

Mercury in marine acid.

The marine acid, in its common phlogifticated ftate, does not act on mercury, at leaft in its ufual ftate of concentration;

but Mr. HOMBERG, in the Paris Memoirs for the year 1700, assures us, he dissolved mercury in marine acid, whose specific gravity was 1,300, by keeping it some months in digestion. The authors of the *Cours de Chymie de Dijon* affirm also its solubility in this acid, though in very small quantity. The dephlogisticated marine acid, in a vapourous state, certainly acts upon it, though while in a liquid state it is too weak, by reason of its dilution.

Precipitate, *per se*, is also soluble in marine acid, with the assistance of heat. 100 grs. of sublimate corrosive contain 77 of mercury, 16 of real acid, and 6 of water. 100 grs. of mercurius dulcis contain 86 of mercury, and 14 of acid and water.

Zinc in vitriolic acid.

100 grs. of zinc require for their solution 100 grs. of real acid, whose proportion to that of water may be as 1 to 8, 10, or 12, applying heat towards the end, when the acid is almost saturated. A small quantity of black powder always remains undissolved. The product of inflammable air is 100 cubic inches. It is soluble in the concentrated vitriolic acid, with the aid of heat.

100 grs. of vitriol of zinc contain 20 of zinc, 22 of acid, and 58 of water.

The calces of zinc, if not exceedingly dephlogisticated, are also soluble in this acid.

Zinc in nitrous acid.

100 grs. of zinc require for their solution 125 grs. of real nitrous acid, whose proportion to that of water is as 1 to 12, applying from time to time a slight heat. If a concentrated acid be

be ufed, lefs will be diffolved, as much of the acid will efcape during the effervefcence. I could procure no nitrous air from the folution by any management, as the nitrous acid is in part decompofed during the operation.

The calces of zinc, if not too much dephlogifticated, are alfo foluble in this acid.

Zinc in Marine Acid.

The fame quantity of zinc requires of this acid 210 grs. the proportion of real acid in the menftruum being as 1 to 9, and ufing from time to time a flight heat. If a lefs dilute acid be ufed, more real acid will be requifite, as much of it will efcape during the effervefcence.

The calces of zinc are alfo foluble in this acid.

Bifmuth in vitriolic acid.

200 grs. of oil of vitriol, whofe fpecific gravity was 1,863, diffolved but three grs. of wifmuth in a ftrong heat; but flightly dephlogifticated a greater quantity. 400 grs. of fpirit of vitriol, whofe fpecific gravity was 1,200, diffolved but one grain. The calces of wifmuth are much more foluble. The folution of the 3 grs. afforded 4 cubic inches of vitriolic air.

Bifmuth in nitrous acid.

The folution of 100 grs. of bifmuth require but 100 grs. of real nitrous acid, whofe proportion to water fhould be as 1 to 8 or 9. In this laft cafe, a gentle heat may be applied. This folution affords 44 cubic inches of nitrous air. The calces of bifmuth are alfo foluble in this acid.

Bifmuth

Bifmuth in marine acid.

400 grs. of fpirit of falt, whofe fpecific gravity is 1,220, diffolved only 3 or 4 grs. of bifmuth.

Nickel in vitriolic acid.

100 grs. of concentrated vitriolic acid diffolve about 4 of nickel, with the affiftance of a ftrong heat. The calces of nickel are much more foluble.

Nickel in nitrous acid.

100 grs. of nickel require for their folution 112 grs. of nitrous acid, whofe proportion to water is as 1 to 11 or 12, affifted with a moderate heat. A concentrated acid acts fo rapidly that much is diffipated. The product of nitrous air is 79 cubic inches. The calces of nickel are alfo foluble in this acid.

Nickel in marine acid.

200 grs. of fpirit of falt, whofe fpecific gravity is 1,220, diffolved 4 or 5 grs. of nickel, without the affiftance of heat. A weaker acid diffolves lefs, and requires the affiftance of heat. In all thefe cafes of difficult folution more of the metal will be taken up by diftillation and cohobation ; but the proportion will be difficult to affign.

The calces of nickel are alfo difficultly foluble in this acid.

Cobalt in vitriolic acid.

100 grs. of cobalt require 450 grs. of real acid, whofe proportion to its water is not lefs than 1 to $\frac{7}{10}$, and a heat of

4   270°

270° at leaft. By pouring warm water on the dephlogifticated mafs a folution is obtained.

The calces of cobalt are ftill more foluble; even a dilute acid will ferve.

Cobalt in nitrous acid.

100 grs. of cobalt requires 220 grs. of real nitrous acid, whofe proportion to water is as 1 to 4, giving towards the end a heat of 180°.

The calces of cobalt are foluble in this acid.

Cobalt in marine acid.

100 grs. of fpirit of falt, whofe fpecific gravity is 1,178, diffolves, with the affiftance of heat, 2½ grs. of cobalt. A more concentrated acid will diffolve more.

The calces of cobalt are more foluble in this acid,

Regulus of antimony in vitriolic acid.

100 grs. of regulus of antimony require for their folution 725 grs. of real acid, whofe proportion to water is as 1 to $\frac{7}{10}$, and a heat of 400°. More regulus fhould be employed than is expected to be diffolved, and the refulting falt requires a large quantity of water to diffolve it; for the concentrated acid lets fall much when water is added to it. A lefs concentrated acid will alfo diffolve this femi-metal, but in fmaller quantity.

The calces of antimony, even diaphoretic antimony, are fomething more foluble.

Regulus of antimony in nitrous acid.

100 grs. of this femi-metal require 900 grs. of real nitrous acid, whofe proportion to water is as 1 to 12, aided with a

heat

heat of 110°. The folution, however, becomes turbid in a few days.

The calces of antimony are foluble in a much lefs degree.

Regulus of antimony in marine acid.

100 grs. of fpirit of falt, whofe fpecific gravity is 1,220, diffolve about 1 gr. of regulus, with the affiftance of a flight heat. Spirit of falt, whofe fpecific gravity is 1,178, alfo acts upon it, but diffolves ftill lefs. I believe the concentrated acid would, in a long time, and with the help of a gentle heat, diffolve much more of it.

The calces of antimony are much more foluble in this acid.

Regulus of arfenic in vitriolic acid.

200 grs. of oil of vitriol, whofe fpecific gravity is 1,871, diffolve 18 of regulus of arfenic in a heat of 250°. Of thefe about 7 cryftalize on cooling, and are foluble in a large quantity of water.

The calces of arfenic are more foluble in this acid.

Regulus of arfenic in nitrous acid.

100 grs. of this femi-metal require 140 grs. of real nitrous acid, whofe proportion to water is as 1 to 11, and the affiftance of heat. It is foluble in a lefs or more concentrated acid, but in a leffer degree. This folution affords 102 cubic inches of nitrous air. The barometer at 30, and the thermometer at 60.

The calces of arfenic are alfo foluble in this acid.

Regulus of arfenic in marine acid.

100 grs. of fpirit of falt, whofe fpecific gravity is 1,220, diffolve 1½ grs. of regulus of arfenic; the marine acid, in its

common

common dilute ftate, that is, whofe fpecific gravity is under 1,17, does not at all affect it.

The calces of arfenic are lefs foluble in this acid than in the vitriolic or nitrous.

We have now gone through moft of the bafes to which acids are capable of uniting (manganefe and platina I have purpofely omitted, as I was not poffeffed of a fufficient quantity of either in that degree of purity requifite for exact experiments). We have alfo feen the quantity of the mineral acids requifite to faturate each bafis, except the metallic bafes, all of which require an excefs of acid, not only to diffolve them, as in moft cafes much of it flies off with the phlogifton in an aërial form, but alfo to keep them in folution. The quantity of any bafis, taken up by a given quantity of any of thefe acids, is eafily found; for if 100 grs. of any bafis take up, at the point of faturation, or require for their folution, the quantity a of any acid, the quantity taken up or diffolved by 100 grs. of that acid will be $\frac{10000}{a}$.

The proportion of ingredients which I have affigned to different neutral falts appears, at firft fight, very different from that which Mr. BERGMAN has afcribed to them. This for fome time made me very uneafy, as I have the higheft confidence in the fkill and judgement of that excellent chymift; but on a ftrict examination I have found, that the difference is more apparent than real. Mr. BERGMAN has never attempted to afcertain the quantity of *real* acid in any fubftance; but has, according to the cuftom of all preceding writers, beftowed the title of *acid* on thofe liquids which contain it in the moft concentrated, or at leaft in a very concentrated ftate, but which

ftill confeffedly contain fome undetermined proportion of water, and by the quantity of water he commonly underftands that which is retained by cryftallization: thus, in his firft vol. p. 137. he fays, that 100 grs. of vitriol of iron contain 23 of iron, 39 of vitriolic acid, and 38 of water. But in his treatife *De Produ&ctis Vulcanicis,* § 12. he fays, that 100 grs. of vitriol of iron contain 24 of iron, 24 of *dephlegmated* vitriolic acid, and 52 of water; and this laft calculation fcarcely differs from mine, as I affign to 100 grs. of vitriol 25 of iron, 20 of real vitriolic acid, and 55 of water. The difference manifeftly arifes from the quantity of water ftill contained in his dephlegmated acid. The moft material difference between us regards the quantity of the mineral acids taken up by alkalies; for, according to his and Mr. SCHEFFER's experiments, they take up more of the vitriolic than of the nitrous, and more of the nitrous than of the marine; whereas, according to Mr. HOMBERG's, Dr. PLUMMER's, Mr. WENZEL's, and my experiments, this does not happen. This difference arifes in all probability from the different degrees of evaporation by which the cryftals of thefe falts are obtained; for which reafon I did not examine the quantity of the cryftals, which muft be variable, but that of dry falt, left after thorough evaporation. With regard to the quantity of earth and metallic bafis in different falts, Mr. BERGMAN's experiments and mine agree almoft intirely.

The advantages refulting from thefe inquiries are very confiderable, not only in promoting chymical fcience, which, being a phyfical analyfis of bodies, effentially requires an exact determination, as well of the quantity and proportion, as of the quality of the conftituent parts of bodies, but alfo in the practical way. Thus, in the firft place, it is well known, that
feveral

feveral important proceffes are very inaccurately defcribed by antient chymical writers, and even by fome of a modern date, they frequently, for inftance, defcribe the acid they employed by reference to the quantity of fixed alkali, earth, or metal, a given quantity of fuch acid was capable of neutralizing or diffolving. Now the foregoing obfervations immediately inform us of the quantity of real acid capable of performing that effect; the remainder, therefore, muft have been water; and the quantity of real acid and water being known, the fpecific gravity is eafily found by the help of the foregoing tables, and thus an acid of the fame ftrength may be formed. Thus SCHLUTTER, in the beft treatife on Effaying yet extant *, informs us, that the beft aqua fortis for parting filver from gold is that of which a pound diffolves one mark, that is, half a pound of filver: then 1000 grs. of it fhould diffolve 500 of filver. Now, by the foregoing experiments, we find, that 100 grs. of alloyed filver require 38 of real acid for their folution; confequently 500 grs. of filver will require 190 grs.; confequently 1000 grs. of fuch fpirit of nitre fhould contain 190 grs. of real acid and 810 of water. Then recurring to the table of the nitrous acid, I find, by the rule of proportion, that the fpecific gravity of this acid muft be about 1,261; for as 190 is to 810, fo is 393 acid to 1675 of water. This proportion of water is fomewhat greater than that I ufed, but SCHLUTTER ufes a fand heat.

2dly, The importance of this knowledge in the art of pharmacy is very obvious, efpecially with regard to medicines formed of metallic fubftances, whofe powers depend on the proportion of their ingredients, and their action on each other.

3dly, This degree of precifion muft tend confiderably to the

* Vol. I. p. 332. French edition.

improvement of the arts of dying and enamelling, the proceffes by which many of their ingredients are procured being at prefent much too vague. Thus the procefs at prefent ufed for preparing the precipitate of CASSIUS frequently fails, the ftrength of the acids not being fufficiently afcertained.

4thly, The ufes of this knowledge in the examination of mineral waters, and in effaying of ores, have been amply proved in the elaborate treatifes which the celebrated BERGMAN has lately given us on thefe fubjects. And I may further add, that the knowledge of the quantity of acid requifite for the folution of different metallic fubftances may alfo furnifh us with a new criterion for diftinguifhing them from each other, and the purer from their alloys, and in fome cafes inform us of the quantity and quality of the alloy : thus, 100 parts pure filver require lefs of the nitrous acid to diffolve them than 100 grs. of ftandard filver ; thus alfo, by diffolving in fpirit of falt any metallic fubftance fufficiently foluble therein, we may know whether it contains the fmalleft particle of filver, quickfilver, or arfenic, as thefe are almoft infoluble therein, or of regulus of antimony, cobalt, nickel, or wifmuth, of which it alfo takes but a fmall proportion.

But the end which of late I had principally in view, was to afcertain and meafure the degrees of affinity or attraction that fubfift betwixt the mineral acids, and the various bafes with which they may be combined, a fubject of the greateft impertance, as it is upon this foundation that chymiftry, confidered as a fcience, muft finally reft ; and though much has been already done, and many general obfervations laid down on this head, yet fo many exceptions have occurred even to fuch of thefe obfervations as feemed to have been moft firmly eftablifhed, that not only a variety of tables of affinity have been formed,

but

but many very eminent chymifts have been induced to doubt, whether any general law whatfoever could be traced. But, as the judicious BERGMAN well obferves, it were much more reafonable to examine the circumftances of thefe exceptions, which undoubtedly arife from the introduction of new powers, and lay down rules qualified with fuch reftrictions as are obferved in the action of thefe antagonift powers. This is the plan I have followed ; but before I proceed to explain myfelf, I muft open the fubject in a more general way.

Chymical affinity or attraction is that power by which the invifible particles of different bodies intermix and unite with each other fo intimately as to be infeparable by mere mechanical means. In this refpect it differs from magnetic and electrical attraction. It alfo differs from attraction of cohefion in this, that the latter takes place betwixt particles of almoft all forts of bodies whofe furfaces are brought into immediate contact with each other ; for chymical attraction does not act with that degree of indifference, but caufes a body already united to another to quit that other and unite with a third, and hence it is called *elective* attraction. Hence attraction of cohefion often takes place betwixt bodies that have no chymical attraction to each other ; thus regulus of cobalt and wifmuth have no chymical attraction to each other, for they will not unite in fufion, yet they cohere with each other fo ftrongly, that they can be feparated only by a ftroke of a hammer.

Hence bodies, which refufe to unite to each other chymically when they are moft minutely divided, as when both are in a vaporous or aërial ftate, or when both are in a liquid ftate, may be judged, in the firft cafe, to have none ; or in the fecond cafe, to have at beft but a very fmall affinity to each other. But thofe that unite, when one of them only is in a liquid ftate,

may

may be said to have a strong affinity to each other, and it is thus that acids unite to alkalies, earths, and metals, for the most part.

In order to determine the degrees of affinity, Mr. GEOFFROY has laid it down as a general rule, that when two substances are united, and either quits the other to unite to a third, that which thus unites to this third substance must be said to have a greater affinity to it than to the substance it has quitted. This undoubtedly is the case when only two attractive powers are concerned; thus, when selenite is decomposed by a caustic fixed alkali, it is evident, that the vitriolic acid has a stronger affinity to the alkali than to the earth; but in many cases a decomposition, seemingly single, is in fact double, and the result of the action of more than two powers, and then it is not easy to know which is the greatest, nor consequently to determine the degree of attraction; for instance, the vitriolic acid unites to a mild fixed alkali, and expels the fixed air from it, yet it does not necessarily follow, that the vitriolic acid attracts, or is attracted, by the alkali more strongly than the aërial acid; for though there appears here only a single decomposition, yet in reality a sort of double decomposition takes place, the vitriolic acid giving out its fire to the aërial, while the aërial resigns the alkali to the vitriolic; and hence a decomposition might well take place, even on the supposition that the affinity of both acids to the alkali was equal: therefore, to attain any certainty in this matter, it is necessary to ascertain the quantity and force of each of the attractive powers, and denote it by numbers.

Mr. MORVEAU was the first who perceived the necessity of this calculation, and he has accordingly communicated to us, in numbers, a table of the attractive power of mercury with respect to metals; but his method is incapable of being generalized.

lized. Mr. WENZEL had alfo an eye to fuch calculation; but his method is much more defective. It is only this, " To " difcover (fays he) the quantity of affinity which the nitrous " acid bears to the different fubftances with which it is capable " of uniting, let fmall equal cylinders of each of the metals " be covered over, except at one end, with melted amber, and " then expofed to equal quantities of the fame fpirit of nitre, " and in the fame temperature ; then let the times of the folu- " tion of each be noted. *The affinity of the acid to each of thefe* " *metals will be inverfely as the times neceffary for the folution of* " *equal quantities of them.*" And as he well knew that fpirit of nitre, of the fame degree of concentration, would not act equally on each of them, he required that it fhould be diluted in fome cafes, and undiluted in others, and allowance to be made for this in the fubfequent calculation. But alkalies and earths are here intirely omitted; and even as to metals no conclufion can be drawn by this method. Tin and regulus of antimony are moft rapidly attacked by this acid, lead and cop- per much more flowly; yet it is well known, that its affinity to lead is much ftronger than its affinity to tin, and its affinity to copper greater than to regulus of antimony. Silver and quickfilver are more flowly diffolved, and yet the affinity of the nitrous acid to thefe metals, as will be feen in the fequel, is by far the greateft.

Neither can this method be in any wife applied to the eftima- tion of the affinities of the other mineral acids; for though the vi- triolic and marine acids diffolve very flowly, difficultly, and fpa- ringly, feveral metals that are copioufly and readily diffolved by the nitrous, yet they both have a ftronger affinity to thofe very metals than the nitrous has to them, as is evident with regard to filver, mercury, and lead, which are precipitated from the

nitrous by the vitriolic and marine, though the two firſt are
infoluble in the marine, and all three difficultly foluble in the
vitriolic.   Accordingly, we do not find that Mr. WENZEL has
ever made the propoſed experiments, at leaſt he makes no men-
tion of their refult.

The difcovery of the quantity of real acid in each of the
mineral acid liquors, and the proportion of real acid, taken up
by a given quantity of each baſis at the point of faturation, led
me unexpectedly to what feems to me the true method of in-
veſtigating the quantity of attraction which each acid bears to
the feveral baſes to which it is capable of uniting; for it was
impoſſible not to perceive,

Firſt, That *the quantity of real acid, neceſſary to faturate a
given weight of each baſis, is inverſely as the affinity of each
baſis to fuch acid.*

Secondly, That *the quantity of each baſis, requiſite to faturate
a given quantity of each acid, is directly as the affinity of fuch
acid to each baſis.*

Thus 100 grs. of each of the acids require for their fatura-
tion a greater quantity of fixed alkali than of calcareous earths,
more of this earth than of volatile alkali, more of this alkali
than of magneſia, and more of magneſia than of earth of
allum, as may be feen in the following table.

Quantity of baſis taken up by 100 grs. *of each of the mineral acids.*

	Veg fixed alkali. Grs.	Min. alkali. Grs.	Calcar. earth. Grs.	Vol. alkali. Grs.	Mag- neſia. Grs.	Earth of allum. Grs.
Vitriolic acid	215	165	110	90	80	75
Nitrous acid	215	165	96	87	75	65
Marine acid	215	158	89	79	71	55

As

As thefe numbers agree with what common experience teaches us concerning the affinity of thefe acids. with their refpective bafes, they may be confidered as adequate expreffions. of the quantity of that affinity, and I fhall in future ufe them as fuch. Thus the affinity of the vitriolic acid to fixed vegetable alkali, that is, the force with which they unite, or tend to unite, to. each other, is to the affinity with which that fame acid unites to. calcareous earth as 215 grs. to 110; and to that which the nitrous acid bears to calcareous earth as 215 grs. to 96, &c. But before I proceed further in the comparifon of thefe forces, it is neceffary to fay fomething of the nature of *faturation.*

A body is faid to be *faturated* with another, when. it is fo intimately combined with that other as to lofe fome peculiar characteriftic property, which it poffeffes when free from that other. Thus acids poffefs the property of changing the juice of turnfol, or infufion of litmus, *red.* According to Mr. BERGMAN one grain of the moft concentrated oil of vitriol will give a vifible rednefs to 172,300 grs. of this infufion, and one cubic inch of water, faturated with fixed air (the weakeft of all acids, as is generally thought) of which water takes up only about its own bulk, and confequently 253 grs. take up only about half a grain, reddens 50 cubic inches, that is, about 12,650 grs. of the infufion. When acids lofe this property they are faid to be faturated: and if both bodies are faturated, the compound is faid to be *neutralized.*

If an acid be united to lefs of any bafis than is requifite for its faturation, its affinity to the deficient part of its bafis is as. the ratio which that deficient part bears to the whole of what the acid can faturate. Thus if 100 grs. of vitriolic acid be united to 55 parts only of calcareous earth, its affinity to. the deficient

55 parts

55 parts ſhould be eſtimated half of its whole affinity, as 55 is the half of 110 ; but its affinity to the retained part is as its whole affinity.

I ſhall now ſhew how all decompoſitions, in which theſe three acids and the above mentioned baſes are alone concerned, may eaſily be explained.

In all decompoſitions we muſt conſider, firſt, the powers which reſiſt any decompoſition, and tend to keep the bodies in their preſent ſtate ; and, ſecondly, the powers which tend to effect a decompoſition and a new union. The firſt I ſhall call *quieſcent* affinities, and the ſecond ſort *divellent*.

A decompoſition will always take place when the ſum of the divellent affinities is greater than that of the *quieſcent* ; and, on the contrary, no decompoſition will happen when the ſum of the *quieſcent* affinities is ſuperior to, or equal to, that of the *divellent* : all we have to do, therefore, is to compare the ſums of each of theſe powers. Thus, if the ſolutions of tartar vitriolate and nitrous ſelenite be mixed, a double decompoſition will take place, a true ſelenite and nitre being the reſult of ſuch mixture.

Quieſcent affinities.		Divellent affinities.	
Vitriolic acid to fixed veget. alkali	215	Vitriolic acid to calcareous earth	110
Nitrous acid to calcareous earth	96	Nitrous Acid to vegetable alkali	215
Sum of the quieſcent affinities	311	Sum of the divellent —	325

Hence a double decompoſition muſt neceſſarily happen.

The ſame double decompoſition will be produced if, inſtead of tartar vitriolate, GLAUBER's ſalt be uſed, 1 MARGR. 392. ; for the ſum of the quieſcent affinities is 261, and that of the divellent 275. So alſo, if *vitriolic ammon.* be uſed for the ſum

of the quiefcent is 186, and that of the divellent 195, or Ep-
fom falt, 1 MARGR. 390. Mem. Par. 1778, p. 339. or *allum*,
1 MARGR. 387. The determinations, however, with regard
to allum are not quite fo exact as the foregoing ; becaufe allum,
whether vitriolic, nitrous, or marine, conftantly retains an
excefs of acid, the exact point of faturation cannot be found as
I have already remarked, and is well known : however, the
fuperiority is on the fide of the divellent affinities, as it fhould
be. If, inftead of a folution of nitrous felenite, that of ma-
rine felenite be mixed with the folutions of the above men-
tioned vitriolico-neutral falts, the fame fort of double de-
compofition will happen, and a true felenite will be formed, 1
MARGR. 382 ; and on calculation it will be conftantly found,
that the fum of the divellent conftantly exceeds that of the
quiefcent affinities.

So alfo, if a folution of tartar vitriolate be mixed with a
folution of nitrous or marine Epfom, a double decompofition
will take place, though no vifible change will appear in the
mixed liquor, as vitriolic Epfom is exceeding foluble in water,
and therefore is not precipitated as felenite is, on account of its
infolubility, Mem. Par. 1778, p. 338. In the firft cafe, the
fum of the quiefcent powers is 290, and of the divellent 295 ;
in the fecond cafe, that of the quiefcent is 286, and of the
divellent 295.

If a folution of GLAUBER's falt be mixed with that of ni-
trous or marine Epfom, an invifible double decompofition will
alfo happen, Mem. Par. ibid. Hence Mr. QUATREMERE
DIJON-VAL, who lately denied this double decompofition (ROZ.
Mai 1782, p. 392.) was certainly deceived. In the firft cafe,
the fum of the quiefcent affinities is 240, and of the divellent
245 ; in the fecond cafe, that of the quiefcent is 236, and of

the divellent 238. Further, if a folution of nitre be mixed with a folution of marine felenite, an invifible double decompofition will enfue, Mem. Par. 1778, p. 341.; the fum of the quiefcent powers being 304, and of the divellent 313.

If a folution of nitrous Epfom be mixed with that of marine felenite, a double decompofition will be the confequence, 17 ROZ. 393.: the fum of the quiefcent affinities being 164, and that of the divellent 167.

From all which I collect, firft, that the quantity of each affinity, as here determined, perfectly coinciding with all the facts hitherto known, which are pretty numerous, may be looked upon as exact or nearly fo. 2dly, That thefe decompofitions are perfectly confiftent with the fuperior affinity which hitherto has been generally afcribed to the vitriolic and nitrous acids with fixed alkalies over that which thefe acids bear to earths, and do not in the leaft infringe the received laws of affinities, as Meff. MARHER, MONNET, and lately Mr. CORNETTE, in the Memoirs of Paris for 1778, p. 339. do infinuate.

There is a fact, however, in that valuable repofitory of chymical knowledge, Mr. CRELL's Chymical Journal *, which at firft fight feems contrary to one of the above determinations; it is there faid, that if folutions of one part allum and two parts common falt be mixed together, evaporated to a certain degree, and fet to cryftallize, a GLAUBER's falt will be found; yet in this cafe the fum of the quiefcent affinities is 233, and that of the divellent but 223. I repeated this experiment without fuccefs, and indeed the author owns it never fucceeds but during the moft intenfe cold.

If it does fucceed at all, the decompofition muft arife from a large excefs of acid in the allum, which acted upon and de-

* 6 THEIL. p. 78.

compofed

compofed the common falt; and this explanation is confirmed by the fmall proportion of GLAUBER's falt, which is faid to be obtained by this procefs; for from 30 lbs. of common falt and 16 lbs. of allum only, 15 lbs. of GLAUBER's falt were produced; whereas, if the whole of the allum were decompofed, there fhould be formed, according to my computation of the proportion of acid in different falts, $29\frac{1}{2}$ lbs., and, according to Mr. BERGMAN's, 22 lbs. of GLAUBER's falt.

Befides thefe powers there exifts another which neutral falts poffefs, of uniting to certain fubftances, without fuffering any, or but a very fmall, decompofition; and thus forming *triple* falts, and fometimes quadruple. This often caufes anomalies, and has not as yet been fufficiently inveftigated *. Volatile alkalies in particular poffefs this power; and hence, perhaps, arifes the difference between Mr. BERGMAN's table and mine, with regard to them and magnefia; for though, when perfectly cauftic, they do not perfectly precipitate magnefia from Epfom falt, it is becaufe they combine with this falt and form a triple falt.

According to my table, the three mineral acids have the fame affinity to vegetable fixed alkalies, which will undoubtedly appear extraordinary to many, as it is well known, that the vitriolic acid decompofes both nitre and falt of fylvius; but it fhould be remarked, that tartar vitriolate is alfo decompofed by the nitrous and marine acids, as Mr. BAUMÈ, MARGRAAF, and BERGMAN, have found; and nitre is decompofed by the marine acid, as Mr. CORNETTE has fhewn at large in the Memoirs of Paris for 1778; and not only thefe falts, but alfo GLAUBER's falt and vitriolic ammoniac, are decompofed by the

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* In my next paper I fhall examine fome exceptions arifing from this fource.

nitrous

nitrous acid; and alfo thefe falts, together with cubic nitre
and nitrous ammoniac, are decompofed by the marine acid, as
Mr. BERGMAN and Mr. CORNETTE have remarked : all which
fhew, that thefe decompofitions are the effect of a double affinity,
or at leaft of compound forces. I always fufpected they arofe
from the different capacities of thefe acids for elementary fire ;
but as the fubject appeared to me of importance, for greater
certainty I made a feries of experiments which differ from
thofe hitherto made in feveral refpects, particularly in this,
that no heat was applied, and the decompofitions were difco-
vered, not by cryftallization, but by tefts.

Firft, I procured equal weights of each of the mineral acids,
containing each the fame quantity of real acid; and throwing
each fuddenly on an ounce of the fame oil of tartar, I had the
following refults, the temperature of all, before mixture, being
68° of FAHRENHEIT. 100 grs. of vitriolic acid, containing
26,6 grs. of real acid projected on 480 of oil of tartar, raifed
the thermometer to 138°.

100 grs. of fpirit of nitre, which alfo contained 26,6 grs.
real acid, projected in the fame manner on 480 grs. of the
fame oil of tartar, produced a heat of 120°.

100 grs. of fpirit of falt, whofe fpecific gravity was 1,220,
and which contained 26,6 grs. of real acid, projected on the
above quantity of the fame oil of tartar, raifed the thermo-
meter from 69 to 129°.

Hence it follows, that the vitriolic acid contains more fpeci-
fic fire, or at leaft gives out more on uniting to fixed alkalies,
than either the nitrous or marine; and, therefore, when the
vitriolic acid comes in contact with either nitre or falt of fyl-
vius, its fire paffes into thefe acids, which are thereby rarefied
to a great degree, and are thus expelled from their alkaline

bafis,

bafis, which is then feized on by the vitriolic. This explana-
tion is confirmed by the following experiments.

Into 400 grs. of fpirit of vitriol, whofe fpecific gravity was
1,362, I put 60 grs. of nitre. The thermometer fell from 68
to 60, and during this time the nitrous acid was not expelled,
for I put in fome filings of copper, and they were not in the
leaft acted upon; but in five minutes after, they vifibly effer-
vefced, which fhews that the nitrous acid began to be expelled.

Again, to 400 grs of oil of vitriol, whofe fpecific gravity was
1,870, I put 60 grs. of nitre: the thermometer immediately rofe
from 68 to 105°, and the nitrous acid was expelled in the form
of a vifible fume. Thefe experiments prove, firft, that neutral
falts are not decompofed, by mere folution, in an acid different
from that which they poffefs. 2dly, That the nitrous acid,
being converted into vapour, had imbibed a large quantity of
fire. But as the vitriolic, in both thefe experiments, was in
much larger quantity than was neceffary to faturate the alka-
line bafis of the nitre, I put 60 grs. of nitre into 64 of the
above fpirit of vitriol, which contained the fame quantity of
real vitriolic acid as the 60 grs. of nitre did of the nitrous, and
added 40 grs. of water, and alfo a few grains of filings of cop-
per. In lefs than two hours the copper was acted upon, and
confequently the nitrous acid was expelled.

Again to about 400 grs. of oil of vitriol, whofe fpecific gra-
vity was 1,870, I put 100 grs. of common falt; it immediately
effervefced, and gave out the marine acid in the form of a white
vapour. A thermometer held in the liquor rofe but 4°; but
when placed in the froth it rofe to 10°, and fell again on being
put into the liquor: whence it follows, that the vitriolic acid
gave out its fire to the marine, and that this latter received

more

more than it could abſorb even in the ſtate of vapour, and hence communicated heat to the contiguous liquor.

From theſe experiments it is evident, that the nitrous and marine acids receive fire from the vitriolic, and are thrown into a vapourous ſtate, or at leaſt ſo much rarefied as to be expelled from their alkaline baſis, notwithſtanding that their affinity to that baſis may be equally ſtrong with that of the vitriolic.

I next proceeded to examine how tartar vitriolate and GLAU-BER's ſalt are decompoſed by the nitrous acid. Into 400 grs. of ſpirit of nitre, whoſe ſpecific gravity was 1,355, and which contained about 105 grs. of real acid, I put 60 of pulveriſed tartar vitriolate. The thermometer, which ſtood at 68°, was not in the leaſt affected by ſtanding in this mixture, and there was ſcarce any ſign of ſolution. To try whether the vitriolic acid was diſengaged, I threw into the liquor a few grains of powdered regulus of antimony: in 24 hours the vitriolic acid was in part diſengaged, for the regulus was acted upon, and the liquor became greeniſh. This ſemi-metal being ſoluble in a mixture of the vitriolic and nitrous acids, but in neither ſingly, however, a great part of the tartar vitriolate ſtill remained un-diſſolved. Afterwards I put the ſame quantity of tartar vitri-olate into 400 grs. of ſpirit of nitre, whoſe ſpecific gravity was 1,478 ; the thermometer roſe from 67 to 79°, the tartar vitri-olate was quickly diſſolved, and the regulus of antimony ſhewed the vitriolic acid was diſengaged.

Hence it follows, that in the laſt experiment the nitrous acid having the ſame affinity to the alkaline baſis as the vitriolic, but giving out, during the ſolution, more fire than was neceſſary to perform the ſolution, the vitriolic receiving this fire was diſ-engaged ; for as it cannot unite to alkalies without giving out fire, ſo when it receives back that fire it muſt quit them. The

reafon why the nitrous acid, which fpecifically contains lefs fire than the vitriolic, gives out fo much, is, that its quantity in both thefe experiments is far greater than that of the vitriolic, it being in the firft as 105 to 17; and in the fecond as 158 to 17.

For this reafon, to 60 grs. of fpirit of nitre, whofe fpecific gravity was 1,355, I added 1000 grs. of water, and into this dilute acid I put 60 grs. of tartar vitriolate, which contained exactly the fame quantity of acid as the 60 grs. of fpirit of nitre. After eight days the tartar vitriolate was almoft intirely diffolved, yet I could perceive no fign of its decompofition, and after evaporation no nitre was found. Hence I conclude, that the nitrous acid can never decompofe tartar vitriolate without the affiftance of heat, but when its quantity is fo great that it contains confiderably more fire, and by the act of folution is determined to give out this fire. The decompofition of GLAUBER's falt and vitriolic ammon. (neither of which, as Mr. BERGMAN obferved, is ever total) may be explained in the fame manner; whereas the vitriolic, ever fo dilute, decompofes both nitre and nitrous ammoniac totally. Tartar vitriolate is alfo decompofed by the marine acid, though very flowly, for the fame reafon, and in the fame circumftances, as it is decompofed by the nitrous acid, as appears by the following experiments. Into 400 grs. of fpirit of falt, whofe fpecific gravity was 1,210, I put 60 grs. of tartar vitriolate. The thermometer was not in the leaft affected, and the falt diffolved very flowly. To try whether the vitriolic acid was difengaged, I added fome pulverifed bifmuth; in twelve hours part of the bifmuth was diffolved, and could not be precipitated by the affufion of water, a fign that it was held in folution by the compound acid, which alone hath the property of

5   preventing

preventing its precipitation by the affufion of water, as Mr. WENZEL has difcovered. Here the quantity of marine acid was much greater than that of the vitriolic, and confequently it contained more fire; but this circumftance alone is not fufficient, it muft befides be determined to give out that fire by the act of folution.   This appears by the experiments of Mr. CORNETTE ; for when he mixed half an ounce of tartar vitriolate, *previoufly diffolved* in water with two ounces of fpirit of falt, the tartar vitriolate was not decompofed, Memoirs, Paris, 1778, p. 49. ; for it being already diffolved, no cold or heat was generated by mixing it with the fpirit of falt, and confequently the latter did not give out any fire. Mr. CORNETTE alfo obferved, that GLAU-BER's falt is eafier decompofed by the marine acid than tartar vitriolate ; this I have alfo experienced, and the reafon is, firft, becaufe GLAUBER's falt is more eafily foluble in fpirit of falt than tartar vitriolate ; and, fecondly, becaufe its alkaline bafis takes up a greater quantity of the real marine acid than of the vitriolic, whereas the bafis of tartar vitriolate takes up an equal quantity of both acids ; confequently the marine gives out more fire in uniting to the bafis of GLAUBER's falt than on uniting to that of tartar vitriolate.

Vitriolic ammoniac is alfo decompofed by the marine acid for the fame reafon ; but in all thefe cafes the quantity of the marine acid muft much exceed that of the vitriolic, or no de-compofition will take place. The decompofition of nitro-neutral falts by the marine acid depends on the fame principles. Mr. CORNETTE found, that cubic nitre was more eafily decom-pofed than prifmatic nitre, and accordingly, during the folu-tion of prifmatic nitre, only 3° of cold were produced ; but, during that of cubic nitre, the thermometer fell 6°, a fign that the fpirit of falt gave out more fire in the latter cafe than

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in the former, and its quantity muft always be greater than
that of the nitrous acid contained in the mineral alkaline bafis,
becaufe this bafis requires for its faturation more of the marine
than of the nitrous acid, as we have already feen.

Yet the nitrous acid, in its turn, decompofes falt of fylvius
and common falt, as Mr. MARGRAF has fhewn ; but it muft
always be in greater quantity than the marine, in order to con-
tain a fufficient quantity of fire for that effect. To 400 grs. of
colourlefs fpirit of nitre, whofe fpecific gravity was 1,478, I
put 60 grs. of common falt, it quickly effervefced and grew
red ; yet the thermometer rofe but 2°, a fign that the marine
acid had abforbed the greater part of the fire which the nitrous
had given out, and was thus expelled : befides, in this cafe,
the fuperior affinity of the nitrous acid to the mineral bafis
haftened the decompofition ; and hence the decompofition hap-
pens without folution, whereas the marine acid does not de-
compofe cubic nitre until it has diffolved it, which is worthy
of notice. This mutual expulfion of the nitrous and marine
acids by each other is the true reafon why aqua regia may be
made, as well by adding nitre or nitrous ammoniac to fpirit of
falt, as by adding common falt or fal ammoniac to fpirit of
nitre, as Mr. CORNETTE has well remarked.

Selenite is decompofed neither by the nitrous nor by the
marine acids, as Meff. CHAPTAL and CORNETTE have obferved.
The reafon is evident on the above principles ; it is diffolved by
neither without the affiftance of heat, and then the folution is
performed by a *foreign* heat, and not by that which thefe acids
give out when they act without the affiftance of heat.

Laftly, whenever a vitriolico-neutral falt, decompofed by
either the nitrous or marine acid, is evaporated to a certain
degree, the vitriolic expels thefe acids in its turn ; for the free

part of the former acids being expelled by the heat of evapora-
tion, the neutral falts begin to cryftallize, and confequently
give out heat ; but the vitriolic being then in greater proportion
re-acts on thefe falts, reftores their fpecific fire to their acid
principle, and recombines with their alkaline bafis, as already
explained.

Hence, though allum is in reality decompofed by the nitrous
and marine acids, yet when the folution of it in either of thefe
acids is evaporated to a certain degree, the vitriolic acid, of
which it contains a larger proportion than any other terrene
falt, re-acts on the nitrous and marine allums, and expels their
acids, as Mr. CHAPTAL has fhewn.

In explaining thefe phenomena I have all along fuppofed the
doctrine of Dr. BLACK to be well known, *viz.* that folids ab-
forb heat during their folution. Both the heat and cold, pro-
duced in different folutions, feem to me to depend on the fame
principle. If the menftruum gives out only *fo much* of its fire
as the folvend can abforb, or *lefs,* then cold is produced ; but if
it gives out *more* of its fpecific fire than the folvend can abforb,
this furplus becomes fenfible, and affects the thermometer by
producing heat in proportion to its quantity.

Of the affinity of the mineral acids to metallic fubftances.

Having thus, in every inftance, eftablifhed the agreement
betwixt the quantity of any alkaline or terrene bafis, taken up
at the point of faturation by a given weight of any of the
three mineral acids, and the quantity of affinity which each of
thefe acids bears to fuch bafis, I naturally extended my views
to metallic fubftances, to try whether this coincidence could be
traced with regard to them alfo; but the difficulties that oc-
curred in this inquiry were fo great, that the fame degree of
certainty muft not be expected as in the foregoing part.

<div align="right">Metallic</div>

Metallic fubftances, when freeft from all foreign mixture, are obtained either in a reguline ftate, or in that of a calx. Thefe calces, if formed by fire, are conftantly combined with more or lefs of the aërial acid, which is very difficultly ex-tracted from them, and very foon re-abforbed; and if formed by folution, they as conftantly retain a portion of their folvent or precipitant, fo that the precife weight of the really metallic part is difficultly afcertained. But though this fhould eafily be effected, ftill they would for the moft part be unfit for my purpofe; becaufe moft of them, when much dephlogifticated, are infoluble in fome or all the acids: hence I chofe metals in their metallic ftate for the fubject of my experiments. Thefe confift of fpecifically different earths and phlogifton, and of this they muft lofe a part before they can be diffolved in acids; but, befides that which efcapes in an aërial form, much more of it, though feparated from the metallic earth, is yet retained in the folution by the compound of acid and calx. It is this calx, thus differently dephlogifticated by the different acids, whofe proportion I endeavoured to afcertain.

The great difficulty that occurred in this inquiry was, that of finding the exact quantity of acid neceffary to faturate the metallic fubftances; for all metallic folutions turn folution of litmus red, and confequently contain an excefs of acid. And the reafon is, becaufe the falts, formed by a due proportion of metallic calx and acid, are nearly infoluble in liquids that do not contain a further quantity of acid; and in fome cafes this quantity, and even its *proportion to the aqueous part of the liquor*, muft be very confiderable, as in folutions of bifmuth. Hence I in vain endeavoured, by cauftic alkalies and lime-water, to deprive thefe folutions of this excefs; for when deprived even of only part of it, many of the metals precipitated, and all

would,

would, if deprived of the whole of it. On this account I was obliged to ufe different methods, of which I fhall here give an inftance. With regard to the folution of filver in the nitrous acid, as it could be had extremely faturate I began with it. 657 grs. of this folution contained, according to my calculation, and allowing for the quantity of acid carried off in the nitrous air, 31,3 grs. of real acid, and 100 grs. of filver. Of this folution I found that 9 grs. gave a vifible *red tint* to as much of a dilute folution of litmus, as a quantity of fpirit of nitre, which contained $\frac{8}{10}$ths of a grain of real acid, and therefore I judged thefe 9 grs. to contain an excefs of acid, amounting to $\frac{8}{10}$ths of a grain ; and if 9 grs. contain fuch an excefs, then the whole folution muft have contained an excefs amounting to $5\frac{6}{10}$ths of a grain, deducting which from 31,38, we find the quantity of acid faturated by 100 grs. of filver to be 25,78 grs. In this manner I proceeded with moft other metallic folutions. The vitriolic folutions of tin, wifmuth, regulus of antimony, nickel, and regulus of arfenic, containing a large excefs of acid, I faturated part of it with cauftic volatile alkali before I tried them with the infufion of litmus, and I ufed the fame expedient with the nitrous folution of iron, lead, tin, and regulus of antimony, and all the marine folutions. The proportion of vitriolic and marine acid taken up by lead, filver, and mercury, I determined by computing the quantity of real acid neceffary to precipitate thefe metals from their folutions in the nitrous acid ; and of all the determinations thefe appeared to me to be the moft exact. However, as all the vitriols of thefe metals are, though in a flight degree, foluble in the nitrous acid, I was obliged to rectify the refult from other confiderations, and the fame neceffity occurred with regard to the marine falts of lead and mercury.

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The refult of thefe experiments was, that 100 grs. of each of thefe acids take up, at the point of faturation of each metallic fubftance, dephlogifticated to fuch a degree as is neceffary for its folution in each acid, the quantities expreffed in the following table, which denote their degree of affinity to each metal.

Table of the affinity of the three mineral acids to metallic fubftances.

100 grs.	Iron.	Copper.	Tin.	Lead.	Silver	Mercury.	Zinc.	Wifmuth.	Nickel	Cobalt	Reg. of antimo.	Reg. of arfenic.
Vitriolic acid	270	260	138	412	390	432	318	250 310	320	360	200	260
Nitrous acid	255	255	120	365	375	416	304	290	300	350	194	220
Marine acid	265	265	130	400	420	438	312	250 320	275 310	370	198	290

Yet I cannot fay that thefe numbers are *precifely* fuch as I could extract from my obfervations on the colour of the folution of litmus; for thefe indications are fo precarious that I did not abfolutely confide in them, but adjufted the numbers, as I thought other phenomena required. However, the deviations were not fo confiderable as to induce a doubt that metallic earths had not almoft all a ftronger affinity to the three acids than even fixed alkalies. Neverthelefs, the common tables, which poftpone metallic fubftances to all others, are in reality juft; they only require a different denomination, being in fact tables of *precipitation* rather than of *affinity*, as far as they relate to metallic fubftances, expreffing by their *order*, what metallic fubftances precipitate others from the different acids. But thefe precipitations are conftantly the refult of a double affinity and decompofition.

decompofition, the *precipitating* metal yielding its phlogifton to the *precipitated* metal, while the *precipitated* metal yields its acid to the *precipitant.* Nor has this efcaped the fagacity of Mr. BERGMAN, 2 N. Act. Upf. 205. who has even confirmed it by experiments which I have repeated, and found exact. Thus, though copper, in its metallic form, precipitates filver and mercury from the nitrous acid with great eafe, yet the calx of copper will precipitate neither. The fuperior affinity of acids to metallic earths, in preference to alkalies and unmetallic earths, requiring further proof, I fhall here demonftrate it in a few inftances, with regard even to thofe metals which are commonly thought to have the leaft affinity to acids. And, firft, that the nitrous acid has a ftronger affinity to filver than to fixed alkalies, appears by a curious experiment of Mr. MONNET's (Diffolution des Metaux, p. 159.). If a folution of filver in nitrous acid be poured into a mixed folution of fixed alkali and common falt, the filver will be precipitated by the marine acid of the common falt, and not by the free alkali contained in the liquor, for a *luna cornua* is found. Now if the nitrous acid had a greater affinity to the free alkali than to the filver, it is evident, that the decompofition would be wrought by the free alkali, and then the filver would be precipitated pure, and not in the ftate of horn filver; but as it is precipitated in the ftate of horn filver, it is plain, its precipitation was not effected by a fingle but by a double affinity. From whence it alfo follows, that the marine acid has a greater affinity to filver than the nitrous has to fixed alkalies. I repeated this experiment with a folution of lead and alfo of mercury in the nitrous acid, and the refult was fimilar, horn lead and marine falt of mercury being formed.

With

With regard to mercury, the experiments of Mr. BAYEN are well known : he has shewn that vitriol of lead and sub-corrosive can be deprived of no more than half of their acid even by cauftic fixed alkalies, 3 ROZ. 293.

Again as to lead, if perfectly dry common falt be projected on lead heated to incandefcence, the common falt will be decompofed, and horn lead formed, 1 MARGRAF. 35 and 38. Nor can this be attributed to the volatilization of the acid by heat; for the alkali is as fixed as the lead, and muft therefore be caufed by the greater affinity of the calx of lead, to which, when dephlogifticated, the acid can unite. Mr. SCHEELE informs us, that if a folution of common falt be digefted with litharge, the common falt will be decompofed, and a cauftic alkali produced, SCHEELE on Fire, p. 175. He alfo decompofes common falt by fimply letting its folution flowly pafs through a funnel filled with powdered litharge. * Mr. TURNER daily decompofes common falt by means of litharge. Mr. SCHEELE alfo decompofes marine felenite, by means of litharge, through fimple mixture, without the affiftance of heat, and the calcareous earth is feparated in a cauftic ftate; which fhews that this falt is decompofed by the fingle fuperior affinity of the metallic calx to the marine acid, SCHEELE on Fire, p. 174.

That acids have lefs affinity to volatile alkalies than to feveral metallic fubftances appears in fundry inftances. Horn filver is foluble in volatile alkalies, as is well known. Now, if this folution be triturated with four times its weight of mercury, the marine acid will combine with the mercury, and not with the volatile alkali; for a *mercurius dulcis*, and not a fal ammoniac, will be formed, as Mr. MARGRAF has fhewn, 1 MARG. 286. If two parts fal ammoniac and one of filings of iron be

* SCHEFFER Chymifche Foceles, § 59.

triturated

triturated together, the fmell of the volatile alkali will imme-
diately be perceived * ; or if, inftead of iron, minium, or diapho-
retic antimony, or zinc, be ufed, that fmell is perceived as
foon as they are mixed, 9 Mem. Scav. Etrang. p. 575. MONNET,
Diff. Met. 209. But it will naturally be afked, how then it
happens, that all metallic folutions are precipitated by alkalies
and earths? The anfwer is eafy; all metallic falts are held in
folution by an excefs of acid. If alkalies and earths did nothing
more than abforb this excefs of acid, a precipitation ought
to take place; but they do ftill more, for they take up the
greater part even of the proportion of acid neceffary to faturate
the metallic earth, and this they are enabled to do by means of
a double affinity; for during the folution of metals, only a
comparatively fmall part of the phlogifton efcapes out of the
folution, the remainder is retained by the compound of acid
and calx : when, therefore, an alkali or earth is added to fuch
a folution, the phlogifton quits the acid, and re-combines with
the calx, while the greater part of the acid unites to the preci-
pitant. Notwithftanding this great affinity of metallic earths
to acids, falts, whofe bafis is a fixed alkali or earth, are in few
inftances decompofed by metals or their calces, by reafon of
the inability of the acids while combined with thefe bafis, and
thereby deprived of a great part of their fpecific fire, to volati-
lize the phlogifton combined with the metallic earths, which
muft neceffarily be expelled before an acid can combine with
them. And as to metallic calces, they are generally combined
with fixed air, which alfo muft be in part expelled.

But ammoniacal falts, containing much more fire (for they
abforb fire during their formation) for that reafon act much
more powerfully on metals. Allowing then the affinity of the

* MONNET, Diffol. Met. 71.

mineral

mineral acids to metallic fubftances to be as above, all double decompofition in which only falts, containing thefe acids united to alkaline terrene or metallic bafes, are concerned, admit of an eafy explanation; nay, I am bold to fay, they cannot otherwife be explained. Thus if a folution of tartar vitriolate, and of filver in the nitrous acid, be mixed in proper proportions (which is always to be underftood), nitre and vitriol of filver will be formed, and this latter for the moft part precipitated.

Quiefcent affinities.		Divellent affinities.	
Nitrous acid to filver	375	Nitrous acid to vegetable alkali	215
Vitriolic acid to vegetable alkali	215	Vitriolic acid to filver	390
Sum of the quiefcent	590	Sum of the divellent powers	605

So alfo if, inftead of a folution of tartar vitriolate, that of GLAUBER's falt, or of vitriolic-ammoniac, or felenite, Epfom, or allum, be ufed; for in all thefe cafes the balance is conftantly in favour of the divellent powers, yet the folutions of felenite and allum produce but a flight precipitation.

I alfo found, that the folution of filver is precipitated by the vitriolic folutions of iron, copper, tin, and probably by many other vitriolic folutions, if for no other reafon at leaft for this, that they conftantly contain an excefs of acid; but if a faturate folution of filver be mixed with a very faturate folution of lead or mercury in the vitriolic acid, the filver will not be precipitated, as I have obferved; and in both cafes the balance is in favour of the quiefcent affinities.

The nitrous folution of filver is alfo decompofed, and the filver precipitated by all *marino* neutral falts, whether the bafis be alkaline, terrene, or metallic, as I have experienced, and

thefe

thefe decompofitions are conftantly indicated by the balance of affinities exhibited as above.

In the fame manner filver is precipitated from the *vitriolic* acid by *marino* neutral falts, whether their bafis be alkaline, terrene, or metallic, as I have found on trial, and as the balance of affinities requires.

The nitrous folution of lead is alfo decompofed, and the lead for the moft part precipitated (unlefs the folution be very dilute) in the form of vitriol of lead by all the *vitriolico* neutral falts; and alfo by all the *marino* neutral falts, except marine falt of filver, which only precipitates it by virtue of its excefs of acid.

The marine folution of lead is decompofed by all *vitriolico* neutral falts, except felenite and vitriol of nickel, which can only precipitate it by virtue of an excefs of acid.

The nitrous folution of mercury is alfo decompofed, and the mercury for the moft precipitated in the form of vitriol of mercury by all vitriolic neutral falts, except vitriol of lead, which can only decompofe it by an excefs of acid.

Nitrous folution of mercury is alfo decompofed by *marino* neutral falts, except the marine falt of filver and lead, which can only affect it by an excefs of acid.

Vitriol of mercury is alfo decompofed by marino neutral falts, which decompofition is alfo apparent by expofing the antagonift powers; yet a precipitation does not always appear as I have remarked, particularly when marine allum is ufed, which I attribute to the facility with which a fmall quantity of the marine falt of mercury is foluble in an excefs of acid. Marine falt of filver decompofes vitriol of mercury, only through its excefs of acid.

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Hence

Hence we fee why horn filver can never be reduced by fixed alkalies without lofs, as Mr. MARGRAAF has fhewn, 1 MARGR. 277.; nor could it be decompofed at all, but that the action of heat helps that of the alkali.

If to a folution of fublimate corrofive oil of vitriol be added, a precipitation will appear; but, as Mr. BERGMAN well remarks, this does not proceed from a decompofition, but from a fubftraction of the water neceffary to keep the fublimate diffolved.

If to a folution of vitriol of iron fome nitrous acid be added, it immediately becomes turbid, becaufe the nitrous acid dephlogifticates the calx of iron too much, but the addition of more acid reftores the tranfparency, as the dephlogifticated calx is ftill foluble by a greater quantity of acid. I omit a number of other curious phenomena, which are explicable on thefe principles.

I have affigned in the foregoing table two different affinities to the vitriolic acid with regard to wifmuth, and alfo to the marine acid with regard to nickel and wifmuth. The firft fhews that which thefe acids bear to thofe metals, when dephlogifticated only by folution in thofe acids. The fecond number, that which the acids bear to them when more dephlogifticated, as they are, when diffolved in the nitrous acid. On the other hand, all the acids have lefs affinity to the calces of iron, zinc, tin, and antimony, when they are dephlogifticated to a certain degree; but as I could give no criterion of this dephlogiftication, I did not attempt to indicate the diminution it caufes in the affinities of acids.

Of

Of the precipitation of metals by each other from the mineral acids.

I am now come to the laſt point of my inquiry, and the moſt difficult to be ſet forth with that degree of preciſion which I have been enabled to attain in the former parts ; for, in the firſt place, it is neceſſary to find the quantity of phlogiſton in each of them, not only in general, but according to their various degrees of dephlogiſtication by each of the acids. In this laſt particular I cannot aſſert that I have attained any thing like a certainty, yet I hope what I advance may not be uſeleſs to chymical readers, as it is not altogether groundleſs, as it con-tradicts no chymical fact, but, on the contrary, is agreeable to many, and affords a ready ſolution of all the phenomena.

Of the abſolute quantity of phlogiſton in metals.

The proportion of phlogiſton in metallic ſubſtances rela-tively to each other has been inveſtigated in ſo maſterly a man-ner by Mr. BERGMAN, that I lay it down as the ground of my inquiries. After his diſcovery all that remained was to find the abſolute quantity of it in any one metal, for then, by an eaſy calculation, it may be determined in all the reſt. The ſub-ſtance I choſe for this purpoſe was regulus of arſenic, as being moſt capable of dephlogiſtication by nitrous acid, though not altogether ſo.'

From 100 grs. of regulus of arſenic, diſſolved in dilute nitrous acid, as already ſeen, 102 cubic inches of nitrous air and $\frac{4}{10}$ ths are obtained, barometer at 30°, thermometer at 60°. I muſt add, that I made the experiment on 5 grs. only, ſo that the calculation relates only to the quantity of air which 100

grs.

grs. *should* give. I repeated the experiment three times with the fame fuccefs. I attempted getting more air from the refiduum left by a gentle evaporation, but though frefh fpirit of nitre grew red with it, the quantity of air was quite inconfiderable.

Now this quantity of nitrous air contains 6,86 grs. of phlogifton, according to the calculation to be feen in my former paper; and hence I conclude, that 100 grs. of regulus of arfenic contains 6,86 grs. of phlogifton. This regulus was made by Mr. WOLFE, and perfectly bright.

Hence the relative proportion of phlogifton in metals being, as found by Mr. BERGMAN, and fet forth in the firft column of the following table, the abfolute quantity will be as fhewn in the fecond column.

	Relative quantity of phlogifton.	Abfolute quantity.
100 grs. Gold	394	24,82
Copper	312	19,65
Cobalt	270	17,01
Iron	233	14,67
Zinc	182	11,46
Nickel	156	9,82
Regulus of antimony	120	7,56
Tin	114	7,18
Regulus of arfenic	109	6,86
Silver	100	6,30
Mercury	74	4,56
Wifmuth	57	3,59
Lead	43	2,70

This point being, as I conceived, of fome importance, I endeavoured to afcertain it ftill further by other experiments: and

as

as filver lofes a certain quantity of phlogifton, which efcapes and feparates from it during its folution in nitrous acid, I conceived, that if the folution was expofed to nothing from which it could re-obtain phlogifton, and thus diftilled to drynefs, and intirely feparated from the acid, as much filver fhould remain unreduced as correfponded with the quantity of phlogifton loft by it. And if this quantity of phlogifton correfponded with that affigned to filver in the foregoing table, that then this table was juft.

For this purpofe I diffolved 120 grs. of clean filings of ftandard filver in dilute dephlogifticated nitrous acid, and obtained from it 24 cubic inches of nitrous air. This folution I gently evaporated to drynefs; by the evaporation I found a little of the filver volatilized, but not more than a quarter of a grain. I then diftilled the dry refiduum, and kept it an hour in almoft a white heat in a coated green glafs retort. During the diftillation abundance of the nitrous acid paffed off, a green and white fublimate arofe in the neck of the retort, and fome paffed even into the receiver. When all was cold I broke the retort, the infide of which was penetrated into its very fubftance with a yellow and red tinge, and partly covered over with an exceeding fine filver powder, which could fcarcely be fcraped off. The remainder of the filver was perfectly white and free from acid, but not melted into a button, and when collected weighed 94 grs.; therefore 26 grs. were loft, that is, were fublimed or vitrified; but of thefe 26 grs. 9 grs. were copper (for 100 grs. ftandard filver contain $7\frac{1}{2}$ of copper); therefore, only 17 grs. of pure filver remained unreduced, being either volatilized or vitrified. The whole quantity of pure filver in 120 grs. of ftandard filver amounts to 111 grs.; then if 111 grs. of pure filver lofe 17 by reafon of its

lofs

lofs of phlogifton, 100 grs. of pure filver fhould lofe 15,3; and by the above table 15,3 grs. of filver fhould contain 0,945 of a grain of phlogifton. Let us now fee whether this quantity of phlogifton correfponds with that which 100 grs. of pure filver really lofe by folution in nitrous acid. 100 grs. of pure filver afford, as already faid, 14 cubic inches of nitrous air, which, by my computation, contain 0,938 of a grain of phlogifton, which differs from 0,945 only by $\frac{7}{1000}$. The un-reduced part of the filver was 15,3 grs.; and, by calculating what it fhould be by reafon of the lofs of the phlogifton con-tained in the nitrous air, it would amount to 14 and $\frac{9}{10}$ths of a grain, a difference certainly immaterial.

In this experiment, only as much of the filver fublimed as could not regain phlogifton; the remainder regained it from the nitrous air abforbed by the folution, and alfo from that which remained united to the acid and calx. If this were not fo, I do not fee why the whole of the filver would not fublime.

Again: Dr. PRIESTLEY having feveral times diffolved mer-cury in the nitrous acid, and revivified it by diftilling over that acid, conftantly found a confiderable proportion of it unre-duced. To try whether that proportion correfponded with my calculation, I have examined the experiment which he made with moft care, and which is to be found in his 4th vol. p. 262. We there find, that having diffolved 17 dwts 13 grs. = 321 grs. of mercury in nitrous acid, $1\frac{1}{2}$ dwt. that is, 36 grs. remained unreduced. Now, according to my calculation, 56 grs. fhould remain unreduced; for 100 grs. of mercury afford 12 cubic inches of nitrous air; therefore 321 grs. fhould afford 38,52, which contain 2,58 grs. of phlogifton, and if (accord-ing to the table) 4,56 grs. of phlogifton be neceffary to metallize 100 grs. of mercury, 2,58 will be neceffary to metallize 56 grs.

of mercury : and I am fatisfied, from my own trials, that more than 50 grs. would be found unreduced if dephlogifticated nitrous acid had been ufed in diffolving the mercury, and the folution performed with heat and a ftrong acid ; but that which Dr. PRIESTLEY ufed, being the red or yellow fort, already contained much phlogifton, which contributed to the revivification of a larger quantity of mercury than would otherwife be found. It is true, that Dr. PRIESTLEY afterwards revivified a great part of what originally remained unreduced; but this happened after it was for fome time expofed to the free air, from which the calces of the perfect metals always attract phlogifton, as is evident in luna cornua, which blackens on expofure to the air, and hence alfo proceed the reductions operated by Mr. BAYEN.

But Dr. PRIESTLEY, to whofe luminous experiments chymiftry is already fo much indebted, has been fo obliging as to furnifh me with fome which tend more directly to elucidate the prefent queftion.

In one experiment he found that nearly 5 dwts. of minium, from whence all its air was extracted, that is, about 118 grs. abforbed 40 oz. meafures of inflammable, that is, 75,8 cubic inches = 2,65 grs. of phlogifton, and were then reduced : then 100 grs. of minium fhould require for their reduction nearly 2,25 grs. of phlogifton. In another experiment, made with more care, he found, that 480 grs. of minium abforbed 108 oz. meafures of inflammable air; according to this then 100 grs. of minium require for their reduction 1,49 grs. of phlogifton ; and in two other experiments he found this quantity ftill lefs. Upon which I remark, firft, that the whole of the minium was not dephlogifticated; for, befides that it is never throughout equally calcined, much of it muft have been

reduced

reduced during the expulſion of its air; ſecondly, that the quantity of the phlogiſton in the inflammable air may have been greater as this varies with its temperature, and the weight of the atmoſphere; ſo that upon the whole theſe experiments confirm the reſults expreſſed in the table.

Of the affinity of metallic calces to phlogiſton.

That inflammable air or phlogiſton is condenſed to a very conſiderable degree by uniting to any metallic ſubſtance, ſo that its ſpecific gravity is not only equal, but much ſuperior, to that of the metallic earth with which it combines, may eaſily be concluded from the example of fixed air, which, by uniting to calcareous earth, acquires a ſpecific gravity equal to that of gold ; and hence, that metallic earth which condenſes phlo- giſton moſt, and in greateſt quantity, uniting to it moſt cloſely, may be ſaid to have the greateſt affinity to it; ſo that if we could find the ſpecific gravity of a calx perfectly pure, both from phlogiſton and fixed air, we could, by comparing its den- ſity with that of the ſame calx when metallized, know the denſity which phlogiſton acquires by its union with ſuch calx ; but to procure ſuch calces hath hitherto proved impoſſible, as, during their dephlogiſtication, they combine with fixed air, or ſome particles of their menſtruum; and hence their abſolute weight is increaſed, though their ſpecific gravity be ſomewhat diminiſhed. From this laſt circumſtance it appears, that the ſpe- cific gravity of calces differs much leſs from that of their reſpec- tive metals than does the ſpecific gravity which the phlogiſton acquires by its union with thoſe calces, from that which it poſſeſſes in its uncombined ſtate; in the ſame manner as the denſity of quick-lime differs much leſs from that of lime- ſtone, than does the denſity which fixed air acquires by its

union with quick-lime from that which belongs to it in its aërial
ftate; and hence, inftead of deducing the quantity of affinity
of metallic calces to phlogifton from the following propofition,
viz. that *the affinity of metallic calces to phlogifton is in a com-
pound ratio of its quantity and denfity in each metal,* I am obliged
to deduce it from this other, *viz.* that *the affinity of metallic
calces to phlogifton is directly as the fpecific gravity of the refpec-
tive metals, and inverfely as the quantity of calx contained in a
given weight of thofe metals.* This latter propofition is an ap-
proximation to the former, founded on this truth, that *the
larger the quantity of phlogifton in any metal is, the fmaller is the
quantity of calx in a given weight of that metal*; and that *the
denfity which the phlogifton acquires, is as the fpecific gravity of
the metal.* This latter propofition, however, is not exactly
true, for this denfity is much greater; yet it is the neareft
approximation I can make, and its defect is fenfible only with
regard to thofe metals which contain a confiderable quantity of
phlogifton, *viz.* gold, copper, cobalt, and iron: with regard
to the reft it is of no importance.

Then the fpecific gravity of metals being as reprefented in
the firft column of the following table, the affinity of their
calces to phlogifton will be as is fhewn in the fecond column.
The third column expreffes thefe affinities in numbers homo-
genous with thofe which exprefs the affinities of acids with
their bafis.

	Specific gravity.			Affinity of the calces to phlogifton.
Gold	19	-	0,25	1041
Mercury	14	-	0,147	612
Silver	11,091	-	0,118	491
Lead	11,33	-	0,116	483
Copper	8,8	-	0,109	454
Wifmuth	9,6	-	0,099	412
Cobalt	7,7	-	0,092	383
Iron	7,7	-	0,090	375
Regulus of arfenic	8,31	-	0,089	370
Zinc	7,24	-	0,0817	340
Nickel	7,33	-	0,0812	338
Tin	7,	-	0,075	312
Regulus of antimony	6,86	-	0,074	308

Here we fee, that the calx of lead has a greater affinity to phlogifton than the calces of any of the imperfect metals, and hence its ufe in cuppellation; for after it has loft its own phlogifton, it extracts that of the bafe metals, and thus promotes their calcination and vitrification.

Though the numbers in the fecond column exprefs tolerably well the greater or leffer affinity of metallic calces to phlogifton, yet they have this inconvenience, that they are not homogenous with thofe that exprefs the affinities of acids to other bafes, which limits their ufe to a narrow compafs, they being, on that account, incomparable with thofe that exprefs the affinities of acids: I therefore endeavoured to find a coincidence between them in fome one inftance, in order to reduce them to the fame ftandard, as will be feen in the next paragraph.

Of

Of the affinity of the vitriolic acid to phlogiston in sulphur.

According to the principle above laid down, this affinity is in a compound ratio of the quantity of phlogiston taken up by 100 grs. of the vitriolic acid and of the density it acquires by its union with the acid. Now 100 grs. of sulphur contain 59 of acid and 41 of phlogiston, and the specific gravity of sulphur is 2,344; therefore, the loss of weight of sulphur in water $=$ $\frac{100}{2,344} = 42,66$ grs. the loss of weight of the acid part of the sulphur is $\frac{59}{4,226} = 13,96$ grs.; therefore, the remainder of the loss of sulphur is the loss of the phlogistic part $= 28,70$ grs.; then the absolute weight of the phlogiston being 41 grs. its density will be $1,429 = \frac{41}{28,7}$; and since 100 grs. of vitriolic acid take up 70 of phlogiston its affinity will be $1,429 \times 70 = 100$. But if the affinity of the vitriolic acid to phlogiston in sulphur had been sought in the same manner with the affinity of metallic calces to phlogiston, the quantity would be the same, though the expression of that quantity would be different, as relating to a different standard; for by that method the affinity would be directly as the density of the phlogiston, and inversely as the quantity of vitriolic acid contained in 100 grs. of sulphur, that is, $\frac{1,429}{59} = ,024$; therefore, this expression answers to, and is equivalent to the former, *viz.* 100. By this means I formed the quantities expressed in the third column, which are homogenous to those which express the affinities of acids to their basis. Thus, the affinity of the calx of gold to phlogiston is 1041, for $::,024 . 100 :: ,25 . 1041$, &c.

The

The third point neceffary for the explanation of the pheno- mena attending the folution of metals, and their precipitation by each other, is to determine the proportion of phlogifton which they lofe by folution in each of the acids, and the affi- nity which their calces bear to the part fo loft. I have not been able to determine this by any direct experiment; for though I might determine the part which efcapes in the form of air, yet I could not that which is equally feparated from the metal, but retained in the folution; yet from various collateral confiderations I am induced to think, the proportion of phlo- gifton, feparated from the metals by the different acids, is, at a medium, as expreffed in the following table.

	Iron.	Copper.	Tin.	Lead.	Silver.	Mercury.	Zinc.	Wifmuth.	Cobalt.	Nickel	Reg. of antimo.	Reg. of arfenic.
By vitriolic acid	$\frac{2}{3}$	$\frac{8}{10}$	$\frac{7}{10}$	$\frac{98}{100}$	Intire	$\frac{87}{100}$	$\frac{85}{100}$	$\frac{85}{100}$	$\frac{93}{100}$	Intire	$\frac{97}{100}$	$\frac{86}{100}$
By nitrous acid	$\frac{2}{3}$	$\frac{81}{100}$	$\frac{7}{10}$	$\frac{88}{100}$	Intire	$\frac{9}{10}$	$\frac{99}{100}$	$\frac{97}{100}$	Intire	Intire	Intire	$\frac{99}{100}$
By marine acid	$\frac{42}{100}$	$\frac{57}{100}$	$\frac{3}{10}$	$\frac{6}{10}$			$\frac{6}{10}$	$\frac{7}{10}$	$\frac{94}{100}$	$\frac{8}{10}$	$\frac{84}{100}$	$\frac{8}{10}$

On this fuppofition the affinity of the calces to the deficient part of their phlogifton may eafily be calculated; for they may be confidered as acids whofe affinity to the deficient part of their bafis is as the ratio which that part bears to the whole, as already faid. Thus the affinity of iron, thoroughly deprived of its phlogifton, being 375, as it lofes $\frac{2}{3}$ds of its phlogifton by folution in the vitriolic acid, the affinity of iron to thefe two- thirds is $\frac{2}{3}$ds of its whole affinity, that is, $\frac{2}{3}$ds of $375 = 250$.

Thefe affinities, together with thofe of the three acids to the feveral calces, are reprefented together in the following table.

Vitriolic

	Iron.	Copper.	Tin.	Lead.	Silver	Mercury.	Zinc.	Wiſmuth.	Cobalt.	Nickel.	Reg. of antimo.	Reg. of arſenic.
Vitriolic acid	270	260	138	412	390	432	318	250.310	360	320	200	260
Calx to phlog.	250	360	218	483	491	532	298	350	300	338	300	320
Nitrous acid	255	255	120	363	375	416	304	290	350	300	194	255
Calx to phlog.	250	363	218	424	491	552	337	400	383	338	308	366
Marine acid	265	265	130	400	420	438	312	250.320	370	275.310	198	290
Calx to phlog.	165	260	104	290	491	500	200	280	360	265	240	300

The affinities of calces to phlogiſton are taken at a medium ; for almoſt all metallic ſubſtances are capable of greater or leſſer dephlogiſtication, according to the ſpecies, concentration, and dephlogiſtication of their menſtruum. The more they are dephlogiſticated, the greater their affinity to phlogiſton ; and, in general, the leſs their affinity to the mineral acids. Yet there is a point of dephlogiſtication at which the attraction of acids to the calces is ſtrongeſt : thus the vitriolic acid attracts biſmuth moſt ſtrongly after it has been dephlogiſticated by the nitrous acid ; and the marine acid attracts both biſmuth and nickel more powerfully, when dephlogiſticated by the nitrous or vitriolic acids.

From theſe *data* we may eaſily conceive, in moſt caſes, what will happen on putting one metal into the ſolution of another.

Thus, if a piece of copper be put into a ſaturate ſolution of ſilver, the ſilver will be precipitated ; for the balance is in favour of the divellent powers.

Quieſcent

Quiefcent affinities.		Divellent affinities.	
Nitrous acid to filver	375	Nitrous acid to copper　-	255,
Calx of copper to phlogifton	363	Calx of filver to phlogifton	491
Sum of the quiefcent affinities	738	Sum of the divellent　—	746

The folutions muft be nearly faturate, elfe a large quantity of the added metal will be diffolved by the free acid, before any precipitation can appear; yet it muft not be intirely faturate, at leaft in fome cafes, as will prefently be feen.

I faid in *moft cafes*, becaufe in fome, particularly where mercury, bifmuth, cobalt, regulus of antimony or arfenic, are ufed, another power intervenes which has not yet been fully inveftigated, *viz.* the attraction of calces to each other, which I fhall occafionally mention.

It is worthy of obfervation, that the precipitating metals are more dephlogifticated by this means than by direct folution in their refpective menftruums, and are even diffolved by menftruums that would not otherwife affect them; becaufe their phlogifton is torn from them by two powers inftead of one: thus, though copper be directly foluble in the vitriolic acid, only when this acid is concentrated and heated to a great degree, yet if a piece of copper be put into a dilute cold folution of filver or mercury in the vitriolic of acid, or even into a dilute folution of iron, expofed to the open air, it will be diffolved; a circumftance which juftly excited the wonder of Mr. MARGRAAF and Mr. WENZEL, who did not apprehend the theory of it: and hence we fee how vitriol of copper may be formed by nature, and why it always contains a mixture of iron.

Of folutions in the vitriolic acid.

This acid diffolves iron and zinc, without the affiftance of heat; becaufe its affinity to their calces is greater than the affinity

nity which theſe calces bear to that portion of phlogiſton which they muſt loſe before they can unite to the acid, as may be ſeen by inſpecting the table; but all other metallic ſubſtances unite to this acid only where it is concentrated and heated.

Of ſolutions in the nitrous acid.

The nitrous acid has leſs affinity to all metallic ſubſtances than either the vitriolic or marine. It has alſo leſs affinity to them than they have to that portion of phlogiſton which they muſt loſe before they can unite to it; yet it diſſolves them all (gold and platina excepted) even without the aid of heat becauſe it unites itſelf to phlogiſton unleſs too dilute; and the heat produced by its union with phlogiſton is ſufficient to promote the ſolution.

But if it be too concentrated, it will not act either on lead or ſilver, without the aſſiſtance of heat, as BOYLE and BOERHAAVE have remarked [*]; for the difference betwixt its affinity to theſe metals, and that of theſe metals to the portion of phlogiſton which they muſt loſe before they can unite to it, is very great; and when it is very concentrated, the liquor does not contain fire enough to throw the phlogiſton and it into an aërial form, and reduce the ſolid to a liquid; the ſame would probably be obſerved with regard to mercury, if it had not been already in a liquid ſtate. STAHL has alſo remarked, that it produces very little heat in diſſolving ſilver, and none in diſſolving lead or mercury [+]. This is eaſily explained, now that we know that ſilver contains but little phlogiſton, and lead much leſs, the heat being evidently produced, according to the

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[*] 1 SHAW's BOERH. 508.　2 SHAW's BOYLE 335.

[+] STAHL ſur les ſels 168.

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law difcovered by Dr. CRAWFORD, by the union of phlogifton
to the acid, for metallic calces produce no heat.   As to mer-
cury, the obfervation is not exact, for its folution is accompanied
with heat, as Mr. LAVOISIER has obferved, 1 LAVOIS. 248.

Of folutions in the marine acid.

This acid is known to dephlogifticate metals lefs than any
other.   Where the portion of phlogifton, neceffary to be fepa-
rated, is more ftrongly attracted than the acid itfelf, it can
operate no folution, or at leaft very flowly, without the aid
of heat; nor even where the attraction of acid is ftronger to
the calx than that of the portion of phlogifton it feparates, if
the proportion of acid to fuch calx be very fmall; becaufe fo
fmall a quantity of acid does not contain fire enough to volati-
lize the phlogifton; and hence heat is neceffary for the folution
of lead in this acid.   The dephlogifticated acid acts more
powerfully.

Of precipitations of and by iron.

The mutual precipitations of iron and copper from the
vitriolic acid by each other, have been well explained in a ge-
neral manner by Mr. MONNET and Mr. BERGMAN; I fhall here
fhew the reafon of thefe precipitations more diftinctly.

If a piece of copper be put into a faturate folution of iron,
frefh made, no precipitation will happen, nor will any of the
copper be diffolved in twelve hours, nor even in a longer time,
if the accefs of air to the folution be prevented; but if the
folution be expofed to the open air, the addition of a volatile
alkali will fhew the copper to have been acted upon in 24
hours, or fooner if heat be applied, and a calx of iron is pre-
cipitated.   The operation of the affinities in the firft cafe is as
follows.

Quiefcent.			Divellent.		
Vitriolic acid to calx of iron		270	Vitriolic acid to copper		260
Copper to its phlogifton	-	360	Calx of iron to phlogifton		250
Sum	- - -	630	Sum	- - -	510

Hence, in this cafe, no decompofition can happen; but in the fecond cafe, much of the phlogifton of the folution of iron having efcaped, the affinity of the calx of iron to acid is diminifhed, and that to phlogifton is increafed, and therefore the quiefcent affinities may be fuppofed,

			and the divellent.		
Vitriolic acid to the calx of iron		240	Vitriolic acid to copper	-	260
Copper to its phlogifton	-	360	Calx of iron to phlogifton		370
		600			630

But from the increafed affinity of the calx of iron to phlogifton it might be inferred, that as the iron recovers its phlogifton, the acid fhould re-act upon it and quit the copper ; and this would certainly happen, if it recovered its phlogifton in fufficient quantity, but the accefs of air and heat prevents its retaining it, at leaft in fufficient quantity.

This increafed affinity of the calx of iron to phlogifton is not a mere fuppofition ; for, if into a folution of iron, fo far dephlogifticated as to refufe to cryftallize, fome frefh iron be put, the impoverifhed calx will re-attract fo much of the phlogifton given out during the folution of the frefh iron, that it will now afford cryftals, as Mr. MONNET has obferved in his excellent Treatife on Vitriolization. The diminifhed attraction of the calx of iron to acids is alfo evident from this experiment,

and

and also from the neceffity of adding more acid to a turbid solution of iron, in order to re-eftablifh its tranfparency. The calces of copper alfo precipitate a dephlogifticated folution of iron, as they fhould, the affinity of the acid to fuch calx of iron being 240, and that to copper being 260. With regard to the folution of iron in nitrous acid, the fame thing happens; but as this folution contains a large excefs of acid, a portion of copper is diffolved even before any of the iron is precipitated.

With regard to a folution of iron in the marine acid, though expofed to the open air, copper precipitates nothing from it in 24 hours.

But if a clean piece of iron be put into a folution of copper in the vitriolic acid, the copper is immediately precipitated; for here the quiefcent and divellent affinities exhibited in the firft fcheme are reverfed, the quiefcent becoming the divellent, and *vice verfâ.* It is needlefs to add, that copper is in the fame manner precipitated by iron from the nitrous and marine acids.

Hence the practice of extracting copper from fome mineral waters by means of iron. Thefe waters, therefore, furnifh afterwards, by evaporation, vitriol of iron; but it is remarkable, that this vitriol is much paler than the common, and lefs fit for dying, 2 SCHLUTTER 507. The reafon of which is, that it is more dephlogifticated, not only becaufe old iron is chiefly ufed, but becaufe copper, containing more phlogifton than an equal weight of iron, deprives it of more of its phlogifton than it would lofe if barely diffolved in the vitriolic acid.

Caft iron, according to SCHLUTTER, will fcarcely precipitate a folution of copper; and in effect Mr. BERGMAN has found that it contains lefs phlogifton than bar iron.

I have

I have always found filver to be eafily precipitated from its folution in the nitrous acid by iron. The fum of the quiefcent affinities being 625, and that of the divellent 746; yet Mr. BERGMAN obferved, that a very faturate folution of filver was very difficultly precipitated, and only by fome forts of iron, even though the folution was diluted, and an excefs of acid added to it *; the reafon of this curious phenomenon appears to me deducible from a circumftance firft obferved by Mr. SCHEELE, in diffolving mercury, namely, that the nitrous acid, when faturated with it, will take up more of it in its metallic form †. The fame thing happens in diffolving filver in the nitrous acid in a ftrong heat; for, as I before remarked, the laft portions of filver thrown in afford no air, and confequently are not dephlogifticated. Now this compound of calx of filver, and filver in its metallic form, may well be unprecipitable by iron, the filver, in its metallic form, preventing the calx from coming in contact with the iron, and extracting phlo-gifton from it: and hence alfo, iron has fometimes been ob-ferved not to precipitate a folution of mercury in this acid ‡.

It has been long thought, that iron may be precipitated from acids by zinc, though NEWMAN long ago denied it; but Mr. BERGMAN has fatisfactorily cleared up this point, by fhewing that zinc cannot precipitate iron from the vitriolic acid, until the folution of iron lofes part of its phlogifton. With regard to the nitrous acid, I found, that zinc does not precipitate iron; but, on the contrary, iron precipitates zinc; but in a fhort time the acid re-diffolves the zinc, and lets fall the iron, which evidently proceeds from the too great dephlogiftication of the calx of iron. But zinc precipitates iron from the marine,

* Differt. de Phlog. Quantitate in Metal. p. 6.
† 39 SUENSK. Handling, p. 70.
‡ 2 CRELL. Nev. Entdeck. p. 266.

though

though with difficulty; for after 24 hours the galls ftill ftruck a black. I fhould alfo add, that iron does not precipitate zinc from the vitriolic acid.

Moft metallic fubftances, precipitated by iron from the nitrous acid, are in fome meafure re-diffolved fhortly after, as the nitrous acid foon dephlogifticates the iron too much, then lets it fall, and re-acts on the other metals and re-diffolves them.

The precipitation of the argillaceous earth from allum by iron is owing to the excefs of acid in the allum which firft dephlogifticates the iron; and when this is dephlogifticated, it attracts the acid more ftrongly. Earth of allum, on the other hand, precipitates iron when the folution of iron is dephlogifticated by heat. It may alfo produce this effect by depriving iron of its excefs of acid which keeps it in folution.

Of precipitations of and by copper.

When filver is diffolved in the nitrous acid, and a piece of copper is put into the folution, it fometimes happens, that the filver is not precipitated, as Dr. LEWIS has obferved [*]. This happens either when the nitrous acid is fuperfaturated with filver having taken up fome in its metallic form, as already obferved; or when the filver is not much dephlogifticated, for then its affinity to phlogifton, which is the principal caufe of its precipitation, is lefs than 491; therefore, the remedy is to heat it and add more acid, by which it is dephlogifticated further. However, the nitrous acid always retains a little filver. SCHLUTTER. 362. Hift. Mem. Par. 1728.

It is commonly faid, that if filings of copper be put into a boiling folution of allum, vitriol of copper will be found, and

* Commercium Philof. p. 157.

the

the earth of allum precipitated.   If this were true it would be
very furprifing, as copper is foluble, even with the affiftance of
heat, only in the concentrated vitriolic acid.   Hence I made
the experiment, and found, that after 20 hours boiling not
the fmalleft particle of copper was diffolved, for the colour of
the folution was not altered by volatile alkalies : and though the
allum was precipitated, it ftill retained its faline form, fo that
it loft only its excefs of acid in this experiment.

Of precipitations of and by tin.

   Tin is not precipitated, in its metallic form, by any metallic
fubftance ; and the reafon is, becaufe its precipitation is not the
effect of a double affinity, but of the fingle greater affinity of
its menftruum to every other metallic earth.   Metals that are
precipitated from the nitrous acid by tin, are afterwards re-
diffolved, becaufe the acid foon quits the tin, it becoming too
much dephlogifticated.

Of precipitations of and by lead.

   Metals diffolved in the vitriolic and marine acids, and preci-
pitable by lead, according to the indication of the balance of
affinities, are yet flowly precipitated, becaufe the firft portions
of lead that are diffolved form falts of difficult folution, which
cover its furface, and protect it from the further action of the
acid ; and yet it contains fo little phlogifton, that a great deal
of it muft be diffolved before it gives out enough to precipitate
the diffolved metals.

   Mr. BERGMAN obferved, that a very faturate folution of lead
is difficultly, if at all, precipitable by iron.   Does not this
alfo arife from fome lead being taken up in its metallic form ?
Iron does not precipitate lead from the marine acid, though a

                                                                pre-

precipitate appears; for this precipitate ftill retains the marine acid: on the contrary, lead precipitates iron from this acid, though very flowly.

Of precipitations of and by mercury.

Though the difference betwixt the quiefcent and divellent powers be very fmall, yet mercury is quickly precipitated from the vitriolic acid by copper; becaufe the attraction of the calx of mercury to phlogifton is very ftrong, and a very fmall proportion of that contained in copper is fufficient to revive it.

Silver does not precipitate mercury from the vitriolic acid, unlefs it contains copper, and then it does precipitate it; yet if filver and turpeth mineral be diftilled, the mercury will pafs in its metallic form, WENZEL 42.; which fhews that the affinity of calx of mercury to phlogifton is increafed by heat. The difference betwixt the quiefcent and divellent powers is indeed very fmall.

Silver appeared to me to precipitate mercury from the nitrous acid, though very flowly, when the folution of mercury was made with heat, and not over faturated; but when the folution of mercury was made without heat, it was not at all precipitated. On the other hand, mercury precipitates filver from this acid, not by virtue of the fuperiority of the ufual divellent powers, but by reafon of the attraction of mercury and filver to each other, for they form partly an amalgama and partly vegetate, and fcarce any of either remains in the folution. The fame thing happens, that is, they vegetate, if folutions of both metals in the fame acid be mixed together.

Silver does not precipitate mercury from the folution of fublimate corrofive; but, on the contrary, mercury precipitates filver from the marine acid: and if a folution of horn filver in volatile alkali be triturated with mercury, the filver will

will be freed from its acid and calomel formed, 1 MARGRAAF 284.; and yet, if calomel and filver be diftilled, the mercury will pafs in its metallic form, and horn filver will be formed, *ibid.* 2?6. The fame thing happens if filver and fublimate corrofive be diftilled, 1 POTT. 338. STAHL *des fels*, 306; the affinity of calx of mercury to phlogifton increafing with the heat.

Of precipitations of and by bifmuth.

With refpe&t to the vitriolic acid I have made the fum of the quiefcent and divellent powers equal, though in fact fometimes the one preponderates and fometimes the other. Wifmuth precipitates nothing from vitriol of copper in 16 hours; nor does copper from vitriol of wifmuth. Copper is faid to precipitate wifmuth from the nitrous acid; but I have alfo feen copper precipitated from this in its metallic form by wifmuth. The variations proceed from the different dephlogiftication of copper.

Of precipitations of and by nickel.

Unlefs nickel be pulverifed it fcarcely precipitates any metal.

Zinc precipitates a black powder from the folution of nickel in the vitriolic and nitrous acid, which Mr. BERGMAN, by a method peculiar to him, has fhewn to confift of arfenic, nickel, and a little of the zinc itfelf. The arfenic attra&ting the calx of nickel *; but zinc precipitates nickel from the marine acid.

The folution of iron in vitriolic acid a&ts on nickel, and that of nickel in this fame acid a&ts on iron; but neither precipitates the other in 24 hours; but on longer reft, iron feems to have the advantage; but iron clearly precipitates nickel

* 1 SUENSK. Handling. 1780.

from

from the nitrous acid; and though nickel feems alfo to preci-
pitate iron, yet this arifes only from the gradual dephlogiftica-
tion of the iron.

Nickel precipitates copper in its metallic form from the
vitriolic acid. It alfo precipitates copper from the nitrous and
marine acids; but copper precipitates arfenic from a nitrous
folution of nickel. The vitriolic and nitrous folutions of lead
feem to act in fpecie on nickel, that is, to diffolve it without
any decompofition, the calces uniting to each other. The vi-
triolic and nitrous folutions of nickel for fome time act on lead
in the fame manner; but at laft nickel feems to have the ad-
vantage. With regard to the marine acid, lead feems to have
the advantage, though a black precipitate is feen, whichever
of them is put into the folution of the other.

Nickel readily precipitates wifmuth from the vitriolic and
nitrous acids; but as to the marine I found each of thefe femi-
metals foluble in the folution of the other, yet nickel precipi-
tates wifmuth very flowly, and only as to part; and wifmuth
precipitates a red powder, which I take to be ochre, from the
folution of nickel.

Nickel and tin are flightly acted on, each by the falt of the
other; but the precipitations are as indicated by the balance of
affinities.

Of precipitations of and by cobalt.

Cobalt is not precipitated either from the vitriolic or nitrous
acid by zinc; but it feemed to me to be precipitated by zinc
from the marine acid.

Though iron precipitates cobalt from the three acids, yet I
found much of the cobalt retained both by the vitriolic and
nitrous acids, particularly the latter, which, after letting fall

the cobalt, afterwards re-takes it, and lets fall the dephlogiſti-
cated calx of iron.

Nickel alſo, though it does not precipitate cobalt itſelf, as
appears by the remaining redneſs of the ſolution, yet conſtantly
precipitates ſome other heterogenous ſubſtance from it. The
ſolution of cobalt in the marine acid becomes colourleſs by the
addition of nickel.

Wiſmuth is ſoluble in the vitriolic and nitrous ſolutions of
cobalt, and cauſes a ſmall white precipitate, but does not affect
the true cobaltic part. Theſe ſolutions in vitriolic acid cannot
be attributed to an exceſs of acid, as they are made in a dilute
acid, and without heat. Copper alſo precipitates a white ſub-
ſtance from the nitrous ſolution of cobalt, which I take to be
arſenic.

It is difficult to procure either nickel or cobalt very pure ; it
is evident thoſe I uſed were not ſo.

Of precipitations of and by regulus of antimony.

Copper neither precipitates, nor is precipitated from, the
vitriolic acid by regulus of antimony, at leaſt in three days ;
but vitriol of antimony in ſpecie diſſolves it ſlowly.

The regulus is alſo acted upon by vitriol of lead, for it be-
comes red after remaining 16 hours in the ſolution of that vi-
triol ; and lead ſcarcely precipitates it from the vitriolic acid.

I alſo found, that powdered regulus precipitates vitriol of
mercury very ſlightly.

Wiſmuth neither precipitates, nor is precipitated by, this
regulus from the vitriolic acid in 24 hours.

Though tin precipitates this regulus from the nitrous acid,
yet if the regulus be put into a ſolution of tin in this acid, in
16 hours neither will be found in the ſolution, either
by

by reafon of the dephlogiftication, or of the union of the calces to each other.

Iron does not precipitate this regulus intirely from the marine acid, but a triple falt feems to be formed, confifting of the acid and both calces. The regulus is alfo foluble in marine falt of iron.

Neither does copper precipitate the regulus from marine acid in 16 hours; and if the regulus be put into marine falt of copper it will be diffolved, and volatile alkalies will not give a blue but a yellowifh white precipitate, fo that here alfo a triple falt is formed.

Of Precipitations of and by regulus of arfenic.

The folutions of arfenic act in moft cafes like two acids: thus iron, copper, lead, nickel, and zinc, are acted on by vitriol of arfenic (that is, its folution in vitriolic acid) but fcarce give any precipitate.

Neither does iron precipitate arfenic from the nitrous acid, but copper does, and even filver gives a flight white precipitate; but regulus of arfenic precipitates filver completely in 16 hours. Hence the former precipitate feems to be a triple falt.

Mercury alfo flightly precipitates arfenic from the nitrous acid, and feems to unite to it, yet is itfelf precipitated by regulus of arfenic in 24 hours.

Wifmuth forms a flight precipitate in the nitrous folution of arfenic; but regulus of arfenic forms a copious precipitate in the nitrous folution of wifmuth; fo that I believe the calces unite.

Nickel does not precipitate arfenic from the nitrous acid, but both calces unite; but regulus of arfenic produces a copious precipitate in the nitrous folution of nickel, yet the liquor continues

green;

green ; fo that certainly the nickel is not precipitated ; the white precipitate in this cafe feems to be flightly dephlogifticated arfenic.

This regulus alfo caufes a white precipitate in the nitrous folution of cobalt, but the liquor ftill continues red.

With regard to the marine acid, copper precipitates the regulus, but volatile alkalies do not ftrike a blue with this folution, which fhews the copper unites with the arfenic. Iron alfo precipitates the arfenic. Tin is foluble in marine folution of arfenic, but I could obferve no precipitate, nor does regulus of arfenic precipitate tin.

Neither wifmuth nor the regulus of arfenic precipitate each other from the marine acid in 16 hours. Regulus of antimony is alfo acted upon by the marine folution of arfenic, though it caufes no precipitate, nor does the regulus of arfenic precipitate it.